An Evaluation of Physical Fitness and Physical Activity to Support Therapeutic Exercise Prescription for Individuals with Knee Osteoarthritis in Saudi Arabia: A Mixed-Methods Study

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A thesis submitted to Cardiff University, UK, for the award of the degree of Doctor of Philosophy

(Date of completion: 25/05/2021)

(word count: 82035)

Abstract

Background: Knee osteoarthritis is a highly prevalent condition recognised as a whole-body disease and a leading cause of chronic disabilities. Therapeutic exercise and physical activity promotion are two important therapies for knee osteoarthritis that can help patients to enhance their physical health and enable them to participate in physical activity. However, there is a lack of comprehensive assessment of physical fitness components and physical activity levels of individuals with knee osteoarthritis within the same group in Saudi Arabia. Healthcare providers play an essential role in promoting physical activity in the community for people with knee osteoarthritis. However, in Saudi Arabia, limited studies explored physiotherapy management of knee osteoarthritis, and the barriers and facilitators to physical activity.

Study aims: The overall aim of this study is to evaluate physical fitness and physical activity to support therapeutic exercise prescription for individuals with knee osteoarthritis in a population in Saudi Arabia. This study had two aims. The first aim was to measure physical fitness and physical activity difference between a sample of individuals with knee osteoarthritis and non-arthritic healthy individuals in Saudi Arabia. The second aim was to explore the healthcare providers, knee OA individuals, non-arthritic healthy individuals perspectives on the opportunities and barriers to physical activity in Saudi Arabia for individuals with knee osteoarthritis.

Methods: An emergent sequential, explanatory mixed-methods study design was used. The setting for this study was Saudi Arabia. The study was divided into two phases; phase one was a quantitative study that used a case-control design to assess physical fitness components, physical activity level and barriers and facilitators to physical activity in a sample of individuals with knee osteoarthritis and non-arthritic healthy individuals. Phase two was a qualitative study using semi-structured interviews on a purposive sample from different participant categories. Both phases were integrated at the results and discussion levels to synthesise the findings explain the results of phase one.

Findings and Discussion: The findings of the first phase showed that individuals with knee osteoarthritis had lower physical fitness components compared to non-arthritic healthy individuals ($P < 0.05$). No significant difference was found in the body composition component of physical fitness or physical activity levels ($P > 0.05$), as both groups were mainly categorised as overweight/obese (88.88% of the sampled participants) and physically inactive (90.74% of the sampled participants). Based on the survey, a number of barriers to physical activity in both groups were identified and could indicate that wider beliefs and cultural factors may influence population attitudes towards physical activity in Saudi Arabia. The findings of the second phase produced four main themes; Organization of care of individuals with knee OA, Physiotherapy service and International guidelines practice for knee OA, The Culture of Physical Inactivity, Participants views of the healthcare system for individuals with knee OA. The findings indicated a number of barriers to physical activity in individuals with knee osteoarthritis and limited healthcare providers efforts to promote physical activity that was attributed to inadequate physiotherapists adherence to clinical practice guidelines and evidence-based practice, in addition to several limitations in the current healthcare system in Saudi Arabia.

Conclusion: The comprehensive assessment of physical fitness and physical activity suggest that physical fitness components such as aerobic capacity, muscle fitness, balance and flexibility are reduced in a sample of knee osteoarthritis individuals compared to non-arthritic healthy individuals, and they could be included in the treatment plan for individuals with knee osteoarthritis. In addition, the identified barriers to physical activity could indicate the need for national strategies to include behaviour frameworks to support a theoretical approach in the development of interventions to promote physical activity of individuals with knee osteoarthritis in Saudi Arabia.

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Acknowledgements

I would like to thank my supervisors Professor Kate Button, Professor Nicola Phillips, Doctor Rebecca Hemming, Doctor Philippa Coales (may she rest in peace) and Doctor Sarah Fry. There is no way I could have completed this study without your critical support, invaluable feedback, guidance and encouragement.

A special thanks to my mother and my father (May he rest in peace) who have raised me well and provided me with moral and emotional support in my life.

I'm deeply grateful to my wife Fahda Alshaikh for her understanding and unflinching support throughout the period of this programme. To my kids, thank you for the distractions.

I'm deeply thankful to Doctor Ahmed Barhmain who continusly supported and encouraged me since I was an undergraduate student until I was able to continue my postgraduate studies.

A special thanks to Doctor Ashraf Abdul'aal and Doctor Mohammed Salah for the continuous support and supervision during data collection in Saudi Arabia.

And finally, last but by no means the least, I am thankful to God for seeing me through this. Only you are worthy of worship.

Thanks for all your support and encouragement.

1. Chapter 1: Introduction

This chapter provides a brief overview of the thesis and starts by setting the scene on key terms and concepts used in the main body of the thesis, such as knee osteoarthritis, physical fitness and physical activity. This is followed by background information about Saudi Arabia, the healthcare system, rehabilitation service and physicians' perceptions of physiotherapy service within the healthcare system in Saudi Arabia. The chapter were concluded by describing the thesis structure.

1.1. Setting the scene

1.1.1. Knee Osteoarthritis (OA)

Knee OA is a disease characterised by erosion of articular cartilage with eburnation of subchondral bone and outgrowths of marginal osteophytes, which can be either primary or secondary to trauma (American College of Rheumatology 2019). It is considered as a whole-joint disease that affects several joint parts such as; bone, ligament, cartilage and synovium (Sellam and Berenbaum 2010; Bijlsma et al. 2011a; Arden et al. 2018a). OA is multifactorial and includes a variety of causative factors such as trauma, inflammation, biochemical reactions, mechanical forces and metabolic derangements (Mora et al. 2018). OA is an active process risen from an imbalance between the destruction and repair of joint tissues (Fu et al. 2018). This imbalance is associated with abnormal remodelling of the joint tissues, bone and articular cartilage, driven by several inflammatory mediators (Arden et al. 2018a).

There are several risk factors that may exist alone or combined with others that are associated with the development of knee OA such as old age, female gender, ethnicity, obesity and mechanical factors (Kellgren and Moore 1952; Pereira et al. 2011; Hunter and Bierma-Zeinstra 2019). The typical clinical presentation of knee OA is; individuals aged 45 years and over, with knee pain, brief morning stiffness (less than 30 minutes), crepitus, bony tenderness and enlargement with no palpable warmth (Zhang et al. 2010; Bruyère et al. 2019). However, pain is the most significant symptom and dominant driver of seeking medical care and decision-making, framed within the biopsychosocial model (Neogi

2013a). Knee OA could also be considered as whole-body disease as knee pain could lead to activity limitations and weight gain due to the cycle of disuse (Neogi 2013b; Ingelsrud et al. 2019). Due to the activity limitation, individuals with knee OA may experience fewer social interactions, issues with relationships, emotional well-being, and reduced quality of life (Verges et al. 2019).

The prevalence of knee OA is high, and it is considered a leading cause of chronic disability and the fifth-ranked disability among all forms of disability-led diseases (Dumith et al. 2011; Murphy and Helmick 2012). Globally, the prevalence of asymptomatic uninjured knees with radiographically recognised OA range between 19% to 43% in adults aged over 40 years (Culvenor et al. 2019). Furthermore, the World Health Organisation (WHO) estimated that 9.6% of males and 18.0% of females aged over 60 years have symptomatic OA (WHO 2019). Whereas another study estimated the global prevalence of knee OA to be 3.8%, ranging from 2.3% in males to 4.5% in females (Vos et al.2015). The prevalence of knee OA was higher in higher-income countries at 7.0%, 4.9% in males and 9.1% in females (Culvenor et al. 2019; Vos et al.2015).

Consequently, data from different regions of Saudi Arabia indicates that knee OA prevalence is high compared to other countries. For example, a study of the prevalence of radiographic knee OA in the middle region found that, among 300 participants, 53.3% of males and 60.9% of females had knee OA (Al-Arfaj and Al-Boukai 2002). Moreover, in the northern region, the prevalence of self-reported knee OA among 238 older adults of age 60 years was 24.5% (Alkuwaity et al. 2018), whereas another study found that the prevalence of radiographic knee OA was 39.75% among 410 participants, of whom 25.6% were below the age of 40 years (Alrowaili 2019). However, the studies of the prevalence of knee OA in Saudi Arabia showed various results that could be due to their methodology (self-reported or radiograph knee OA) or due to the region of the sample, which could vary in its environment and culture.

Regards the management of knee OA, there is currently no cure for osteoarthritis (Hunter and Bierma-Zeinstra 2019). Conservative management is considered essential and considered the first line of knee OA treatment (Arden et al. 2018b). Conservative management aims to target the risk factors with approaches such as therapeutic exercise, rest, avoidance of vigorous activities, patient education about the promotion of physical activity and weight loss (Brosseau et al. 2017). In particular, therapeutic exercise offers a wide range of forms such as strengthening, aerobic, flexibility, mind-body (e.g., yoga, Tai Chi), aquatic and walking exercises (Fransen et al. 2015b). However, management guidelines do not provide recommendations for the frequency, intensity, time, and type of exercise expected if following the American College of Sports Medicine (ACSM) guidelines for exercise prescription by the FITT (Frequency, Intensity, Time, and Type) principle to improve or maintain physical fitness and health (American College of Sports Medicine 2017). Consequently, guidelines may not guide physiotherapists to use therapeutic exercise with knee OA but rather confirm its benefits. Hence, the choice of the appropriate form of exercise is based on the physiotherapist's opinion and experience, which may not be an evidence-based decision (Ferreira de Meneses et al. 2016).

1.1.2. Physical Fitness and Physical Activity in Knee OA Individuals

Physical fitness and physical activity are critical indicators of health status (Blair et al. 2001a; Ortega et al. 2008; American College of Sports Medicine 2017); they are closely related with an interchangeable relationship (Blair et al. 1989). Physical fitness (PF) is a set of health and skill-related components associated with the activities and condition of the body (Robson 2013). In comparison, physical activity (PA) is defined as 'any body movement, produced by skeletal muscles and causes energy expenditure' (Bouchard and Stephens 1994). Good PF and PA are associated with numerous health benefits such as maintaining healthy body weight, improving mental health and well-being, reducing the risk of metabolic, cardiovascular diseases, and musculoskeletal complications such as knee osteoarthritis (American College of Sports Medicine 2017). Physical Fitness is linked to good health, and it includes several components such as; body composition, cardiovascular fitness, flexibility, muscle endurance and strength (Corbin et al. 2000; American College of Sports Medicine 2017).

The literature shows that knee OA is associated with limitations in PF components such as reduced muscle strength, aerobic capacity, muscle flexibility and balance (Cavalcante et al. 2015). Individuals with knee OA suffer from a cycle of inactivity that links the OA to the associated disabilities such as reduced PA and PF components (Felson and Chaisson 1997;

Miller et al. 2013; Liow et al. 2017). For example, it has been reported that the most significant symptoms in individuals with knee OA were the associated pain (Arden et al. 2018b), which could start the cycle. OA pain has been identified as a barrier that leads to physical activity limitation (Gay et al. 2018; Coste et al. 2019). Moreover, physical inactivity is a well-known risk factor for chronic conditions such as cardiovascular diseases and diabetes. It could exacerbate disabilities and lead to alterations in PF components such as reduced muscle strength, an increase in weight and reduced aerobic capacity. This in turn, is also considered a risk factor for several chronic conditions and could impact the ability to participate in exercise (Myers et al. 2015; Osteoarthritis Action Alliance 2019).

Therefore, a comprehensive assessment of PA and PF components could be considered an important health indicator, as it may provide the clinicians with a complete picture of the individual's ability to perform functional activities and their physical capabilities. Although there are a large number of studies that have conducted research on each component of PF (an in-depth review of these studies were presented in Chapter 2), these studies have several limitations in the population evaluated and methodology used, which make it challenging to establish clear conclusions. In addition, there are a limited number of studies on the PF of individuals with knee OA which have measured all PF components within the same sample. Hence, the complete picture of physical capabilities and knee OA's effect on individuals may not have been explored yet. Furthermore, considering that the clinical practice guidelines do not provide specific recommendations on the type or form of therapeutic exercise, these PF components may be overlooked in clinical practice, which could affect the quality of care and the individuals' functional activity.

1.1.3. Background on Saudi Arabia

The kingdom of Saudi Arabia is a middle eastern country known as Islam's birthplace and capital. It is the land of the two holy mosques and one of Islam's pillars (Hajj/ Pilgrimage) (Luz 2020). The vast size of the kingdom is recognised as a conservative and tribal population. The weather is known for its scorching summer and cold winter. Saudi Arabia has the largest petroleum and natural gas reserves globally and is the largest exporter (Saudi Gazette 2019); therefore, it is one of the world's wealthiest countries with its vibrant economy (Arne et al. 2019). The General Authority for Statistics (2018) estimated Saudi

Arabia's population to be approximately 33 million compared to 2010, when it was estimated at around 27 million (+14.9% growth). Approximately 20 million are Saudis, and 12 million of the population are non-Saudis. Recent demographics show that 24.84% of Saudi Arabia's population are aged between 0 and 14 years, and 15.38% are aged between 15 and 24 years, and 50.2% are aged between 25-54 years, and 5.95% are aged between 55-64 years, and 3.63% are aged over 65 (Central Intelligence Agency 2018; General Authority for Statistics 2018).

The country is comprised of 13 regions, but the major urban cities are the capital Riyadh, Jeddah, Makkah, Madinah and Dammam (Central Intelligence Agency 2018). Transportation in Saudi Arabia mainly to rely on private cars, planes and recently trains. There is currently a lack of sufficient public transports such as buses. Saudi Arabia has however announced a broad set of socio-economic reforms, known as Vision 2030, that aims to decrease Saudi Arabia's dependence on petroleum, expand the economy and improve several public service sectors as such education, health, infrastructure, leisure and tourism (Kingdom of Saudi Arabia 2030 vision 2016). Therefore, many public services and social changes are occurring to meet the vision of 2030.

1.1.3.1. Healthcare service in Saudi Arabia

Access to healthcare services in Saudi Arabia is a right, free of charge for all the population and is provided mainly (60%) by the Ministry of Health (MOH) through 20 health directorates, with approximately 284 hospitals (Almalki et al. 2011; Ministry of Health 2018). One of the unique features of the Saudi Arabia healthcare service is that, in addition to the residents of the kingdom, it provides free medical care for almost 5 million pilgrims visiting for religious purposes (Walston et al. 2008; Saudi Arabian Unified National Platform 2020). The MOH has more than 3300 primary healthcare centres across the country, which act as gatekeepers for hospitals referrals (Walston et al. 2008; Ministry of Health 2018).

The MOH health services are based on three levels; primary, secondary and tertiary (Almalki et al. 2011). The primary level is provided by primary healthcare centres, which are the first point of contact in the healthcare service, which provides basic preventive and curative care. Individuals who need a higher level of care and interventions are referred to secondary care in public hospitals (Al Asmri et al. 2019; Saudi Arabian Unified National Platform 2020). If the cases are complicated and need more complex care, they are referred to tertiary level care such as specialised hospitals (Almalki et al. 2011; Al Asmri et al. 2019). The primary care centres are available for individuals, families and the community to provide a range of healthcare services such as immunisation, maternal and child health, follow-up for individuals with chronic diseases, dental care services, health education and essential drugs (Al Asmri et al. 2019). However, this system has led to longer waiting time for hospital care, overuse of the emergency departments and increased load on private healthcare services (Walston et al. 2008; Al Asmri et al. 2019). In MOH hospitals, the waiting times for surgeries could be several months to a year. Interestingly, the public perception of the quality of the MOH service is worse than for other healthcare providers (Al Asmri et al. 2019).

The government funds other facilities which are independent of MOH, such as the Ministry of Defense, Ministry of Interior Medical Services, Aviation Medical Services, University Hospitals and National Guard Medical Health Affairs (Walston et al. 2008; Almalki et al. 2011). These bodies provide healthcare services to their defined population that are usually employees and their families, with approximately 47 hospitals around the country that account for 18% of healthcare visits (Ministry of Health 2018). Moreover, the private sector has a large share of the healthcare service, and it had been the primary source of healthcare for non-Saudis until recently allowed to be treated at the MOH (Almalki et al. 2011; Ministry of Health 2015). The private sector provides its service via 163 hospitals with the largest share in Riyadh and Jeddah, which constitute 39% of the total number of patients' visits to health facilities (Ministry of Health 2018).

1.1.3.2. Rehabilitation Service in Saudi Arabia

Rehabilitation is considered to be a strategy of a set of interventions provided to people with disabilities, functional limitations, injuries and trauma (World Health Organization 2019). It encompasses a wide range of services, including physical therapy, occupational therapy, orthotics and prosthetic psychological, speech and rehabilitation medicine clinic (Al-Sobayel et al. 2014). Rehabilitation services are provided mainly in outpatient settings and partly in inpatient settings. In 2018, the total number of attendances in rehabilitation centres in MOH facilities was about 1.6 million cases, most of them (76%) for physiotherapy services (Ministry of Health 2018). Moreover, 57% of individuals who have attended rehabilitation centres in governmental sectors other than MOH were referred for physiotherapy services (Ministry of Health 2018). Physiotherapists, which are the focus of this research, are part of the rehabilitation team, helping to restore movement and function in injured or disabled people and help reduce the pain and prevent injuries in some cases. All physiotherapists must register with the Saudi Commission for Health Specialties (Alghadir et al. 2015a), which has been reported to be approximately 4319 physiotherapists registered to practice (Ministry of Health 2017). Currently, there are 16 universities in Saudi Arabia with undergraduate physiotherapy programs; currently, only four offer physiotherapy postgraduate masters degree studies, and one doctoral-level program at one of the eastern region universities; although there is lack of published evidence, more postgraduate programs are expected to open in the future (Alghadir et al. 2015a; Alshehri et al. 2017). This could highlights the limited number of postgraduate programs as a source for professional development.

The physiotherapy service is based on the secondary level of care and is not available at primary healthcare centres (Al-Abbad and Madi 2020). Therefore, individuals need referrals from physicians to access physiotherapy treatment, or alternatively, they can refer themselves to private practice (Al-Abbad and Al-Haidary 2016). Consequently, it may cause a delay in access to physiotherapy service (Al-Abbad and Madi 2020). Moreover, physiotherapists are expected to assess and treat; yet, they are not involved in screening individuals, and they do not take part in the referral decisions (Al-Sobayel et al. 2014). Therefore, physicians are the dominant decision-makers, and they are the gatekeepers for accessing physiotherapy in Saudi Arabia; their views of physiotherapy would affect the treatment received by the patient (Alshehri et al. 2018; Al-Abbad and Madi 2020). The following section provides a background review of the delivery of physiotherapy service within the healthcare system in Saudi Arabia.

1.1.3.3. The Physicians Perceptions of Physiotherapy Service Within The Healthcare System in Saudi Arabia

There are a very limited number of studies exploring physiotherapy practice and their role in delivering healthcare in Saudi Arabia (a summary of these studies can be seen in Appendix P). For instance, a study by Eisa et al. (2016) explored the awareness, perception and beliefs of physicians working in Saudi Arabia about physiotherapy. Two hundred and eighty physicians with different specialities were recruited to complete a 22-item online questionnaire. Of the 280 participants, 29% were females and 71% males, 46% were physician residents, 30% consultants, 21% registrars and 3% professors. In addition, 50% of participants had a clinical experience of 1–5 years, and the majority (60%) were from the central region in Saudi Arabia.

Regarding the physician knowledge about physiotherapy, the findings show that 51% of respondents stated having some knowledge that mainly came from awareness lectures (17%) and specialised training (35%). However, amongst the 280 participants, only 11% reported that they refer individuals regularly, while the majority (49%) never referred individuals to physiotherapy. The physician's perception of physiotherapy was negative (58%), even though they believed that physiotherapists could decide the patient treatment. Surprisingly, 20% of physicians included prescriptions of physiotherapy treatment type in their referrals. Even more surprisingly, 55% reported that they were not comfortable referring individuals to PT departments without prescriptions. However, this study shows that the scope of the physiotherapy profession may be underestimated, which may highlight the impact of the physicians on physiotherapy autonomy. Nevertheless, it should be noted that the variety of physician specialities included in Eisa et al. (2016) study may not necessarily have direct communication with physiotherapy.

Another perception and attitude were demonstrated in Alshehri et al’s (2018) study, in which the authors investigated the attitude, experience and utilisation of physiotherapy service in Saudi Arabia. A total of 108 physicians responded to an online survey consisting of 4 topics; personal information, attitudes towards physiotherapy services, opinion and experiences towards physiotherapy services and factors related to the extent of use of physiotherapy services. Interestingly, only 50% believed that physiotherapists could prescribe exercise programs, and 44% felt that physiotherapists are not qualified for providing healthcare. This negative attitude was also found in 56% who did not agree with the statement that physiotherapists can assess individuals; only 17.6% agree with direct access to physiotherapists without a referral. However, a large percentage of respondents believed that physiotherapy services have a vital role in healthcare (85.2%), and 59.3% had experience working with physiotherapists. The findings also show that 79.6% discussed physiotherapy interventions with their colleagues.

Alshehri et al. (2018) found that most physicians (92.6%) were confident to refer their patients to physiotherapists as they believed that physiotherapists could deal with patients. Although their findings demonstrated a positive attitude towards physiotherapists; however, the physicians' knowledge of physiotherapy practice was limited as they were not aware of their qualification for assessment and prescription of interventions. Nevertheless, the study had a small sample size with unidentified physician specialities, which may influence the results, in which they might be directly connected to physiotherapy that demonstrate their awareness of the importance of physiotherapy. Moreover, the structure of questions may direct the respondents towards biased answers.

1.1.4. Summary

Knee Osteoarthritis is a highly prevalent disease and the most common form of arthritis. It is a whole-body disease that affects several body parts and considered a leading cause of disability. Several studies found that PF components are affected in knee OA, such as muscle strength, aerobic capacity, body composition, balance, and flexibility. The affected PF and PA were interconnected with the cycle of inactivity in individuals with knee OA unless managed and controlled.

The management of knee OA is based on conservative approaches to tackle the risk factors with therapeutic exercise and PA promotion. These exercises have been considered the first line of treatment in most of the clinical practice guidelines. However, the guidelines do not provide recommendations following the FITT principle for exercise prescription, which may not help the physiotherapists to apply evidence-based practice effectively, and PF components may be overlooked. Moreover, along with the lack of studies on PF components within the same sample and lack of specific therapeutic exercise recommendations, PF components such as balance and flexibility may be overlooked. Hence, individuals with knee OA may not receive the most effective intervention for their disabilities. Therefore, it is essential to do a comprehensive assessment of PF and PA in individuals with knee OA to address the literature's potential limitations and highlight the need to include PF components in the treatments plan.

Referrals to physiotherapy are mandatory as they are the specialist concerned with providing conservative interventions that does not involve surgery such as therapeutic exercises and patient education (Gwynne-Jones et al. 2018; Ho et al. 2019). However, the literature shows that in Saudi Arabia, referrals to physiotherapy were uncertain and based on the physician preference. Hence, it may interfere with physiotherapy service, and individuals may not receive the appropriate treatments. Although the included studies were not focused on knee OA management specifically, it may suggest an issue with physician attitude and physiotherapists' autonomy in providing an effective management plan for the patients. In particular, the literature indicated that physicians might not refer their patients to physiotherapy due to limited knowledge of their qualification, as they provide physiotherapists with a treatment plan (Eisa et al. 2016; Alshehri et al. 2017). Therefore, there might be a significant reduction in the number of referrals to physiotherapy, affecting healthcare service quality. Nevertheless, physiotherapists play a significant role in the management of knee OA, and there is a significant need for studies exploring and evaluating their ability to apply and adherene to evidence-based practice, attitude and experience of physiotherapists in the Saudi Arabian healthcare system.

Therefore, this study aims to evaluate the differences in physical fitness and physical activity levels in people with knee osteoarthritis compared to healthy individuals in Saudi Arabia. The current study also aims to explore people with knee OA, healthy individuals, physiotherapists and physicians perspectives on the opportunities and barriers to physical activity in Saudi Arabia for individuals with knee osteoarthritis.

1.2. Thesis structure

This thesis is divided into two phases, which were undertaken sequentially, with the findings from phase one informing the need and design of phase two. Phase one is a quantitative study that compared differences in physical fitness components and physical activity levels in individuals with knee osteoarthritis and healthy individuals. The first phase is divided into five chapters, which begins with Chapter 2, that is the literature review which critically reviews the literature around Knee Osteoarthritis, physical fitness and physical activity, the relationship between PF and PA, therapeutic exercise and management guidelines, PF and PA levels in knee OA. Chapter 3 is the methods chapter which describes the research design and data collection methods in Saudi Arabia. Chapter 4 is the results chapter and presents the main study findings. Chapter 5 is the discussion chapter that discuss, interpret and compare the findings with the literature, which includes the limitations and recommendations of the first phase of this study and highlights the need for phase two. Chapter 6 outlines the conclusions of phase one.

The first phase section were followed by Chapter 7, a description and justification of emergent mixed methods design, which discusses how phase two could answer phase one results.

Phase two is a qualitative study that aims to better understand the results from phase one by exploring participants perspectives on the opportunities and barriers to physical activity in Saudi Arabia for individuals with knee osteoarthritis and how this impacts healthcare delivery. The second phase has five chapters, which begins with Chapter 8, a brief literature review to identify the literature gap and review the topics needed explanations from phase one. This were followed by the methods (chapter 9), findings (Chapter 10), discussion (Chapter 11) and conclusion (Chapter 12) chapters of phase two.

Chapter 13 integrate the mixed methods results from phase 1 and phase 2, which include recommendations for future research. The final Chapter of this thesis (Chapter 14) is an overall conclusion of the thesis.

Phase 1: Difference in Physical Fitness and Physical Activity in Individuals with Knee Osteoarthritis and non-arthritic healthy individuals

2. Chapter 2: Literature Review

2.1. Introduction

This chapter aims to present and discuss the literature on physical fitness (PF) and physical activity (PA) in individuals with knee osteoarthritis and barriers and facilitators to PA in the Saudi population. It starts with presenting the search strategy utilised in this study, followed by background information on knee osteoarthritis and its management. Then, a review of clinical practice guidelines for knee OA and therapeutic exercise were presented. Later, it provides background information on the terms and concepts of physical fitness and physical activity and their relationship. This lead to a discussion of the relationship between PF, PA and knee OA. Finally, there is a review of studies on PF components, their assessments and levels, and PA levels and barriers in individuals with knee osteoarthritis in Saudi Arabia, which were critically reviewed to identify the gap in the literature. The chapter concluded by summarising the research evidence gap, which lead to the research question and aims of this study.

2.2. Literature search strategy

The literature search aimed to identify relevant studies evaluating the differences in physical fitness and physical activity levels in people with knee osteoarthritis both globally and in Saudi Arabia. In addition, literature exploring barriers and facilitators to PA in Saudi Arabia were included. The systemic literature search was conducted on the following databases based on relevance to the area of research; CINAHL, MEDLINE, PubMed and Scopus. Different sources were used, such as Journals, Books, statistics websites, and references from articles retrieved. The keywords were divided into five concepts; **Physical Activity, Physical Fitness, Knee Osteoarthritis and Management, Barriers and Facilitators to physical activity**, listed in Table 1. The same terms were used across all databases. Boolean phrases (AND, OR, NOT) were used to narrow the results and access only the relevant studies. For example, the first search was carried out to search for all four concepts together (i.e., terms from concept 1; ‘knee osteoarthritis’ were combined with **AND** terms from concept 3; ‘Physical activity’; **OR** ‘inactivity’, **AND** concept 4; ‘Physical fitness’; **OR** ‘Muscle Strength’, **AND** ‘Management’; OR ‘Treatment’). Later, a separate literature search was carried out combining two concepts (e.g., terms in concept 1; ‘knee osteoarthritis’; **OR** ‘Arthritis’ **AND** terms from concept 2; ‘Management’; **OR ‘**Treatment’; **OR** ‘Guidelines’). Similarly, terms from concept 1, ‘Osteoarthritis’, were combined with AND terms from concept 3, 4 and 5, separately.

Table 1 keywords used for the literature search

Concept 1	**Concept 2**	**Concept 3**	**Concept 4**	**Concept 5**
Knee AND Osteoarthritis; OR OA; OR Arthritis; OR Degenerative	Management; OR treatment	Physical activity; or inactivity	Physical fitness; OR physical fitness components	physical activity; OR Adherence; OR Barriers; OR Facilitators; OR limitations; OR Motivation; OR Awareness; OR inactivity
	Physiotherapy; OR Therapeutic exercise; OR strengthening; OR aerobic		Body composition; OR Overweight; OR Obesity OR; BMI; OR Body mass index	
	Recommendations; OR Guidelines; OR Evidence-based practice		Muscle weakness; OR Strength	
			Balance; OR Falls	
			Flexibility	
			Aerobic capacity; OR Cardiovascular fitness; OR VO2MAX; OR Cardiorespiratory fitness; OR oxygen consumption	

The literature search was not limited by time to enable the researcher to retrieve as many up-to-date and relevant studies about physical activity and physical fitness in knee osteoarthritis as possible. The search was limited to the English language, but no geographic limitation was applied, as studies on the Saudi Arabian population were most relevant to the study. Study designs did not limit the search, and randomised control trial, case-study, case-control, cross-sectional, systematic reviews were included. An example from Medline database search can be seen in the following (Table 2).

Table 2 Example of Medline database search

Number	Keyword	results
1	Knee	166228
2	Osteoarthritis	88928
3	Arthritis	221290
4	Degenerative	64404
5	OA	34932
6	2 OR 3 OR 4 OR 5	358211
7	1 AND 6	49241
8	Physical	892841
9	Fitness	91054
10	Strength	323122
11	Weakness	60184
12	Balance	255173
13	Flexibility	73648
14	Aerobic	88054
15	Capacity	549021
16	Cardiovascular	569478
17	Body	1377824
18	Composition	437302
19	Obesity	323939
20	Overweight	74066
21	8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20	4177753
22	Activity	2813554
23	Inactivity	14947
24	Active	1034482

25	22 OR 23 OR 24	3536871
26	7 AND 23 AND 24	2761
27	26 AND “humans” [subjects]	2187
28	Limit 28 to English language	1381

The titles and abstracts of the retrieved studies were assessed for their relevance to the study. The selected studies' full texts were then retrieved and assessed to determine eligibility, which aimed to identify studies that compared physical fitness and physical activity in people with knee OA with a healthy group. The selected studies' reference lists were checked to find additional relevant studies that might have been missed in the initial search. Duplicated studies that were found in more than one database were removed.

The search strategy and assessment of the search results resulted in 38 studies included for critical review. The included studies were related to the clinical practice guidelines, therapeutic exercise, physical fitness and physical activity levels and barriers in individuals with knee osteoarthritis, presented in tables. The critical appraisal was carried out with the Critical Appraisal Skills Programme checklist (2016) to analyse the relevance, significance, and limitation of the included studies.

2.3. Knee Osteoarthritis

2.3.1. The global prevalence of knee osteoarthritis

Globally, OA is the fifth-ranked disability among all forms of disability-led diseases, and knee OA is a leading cause of chronic disability (Dumith et al. 2011; Murphy and Helmick 2012). The world health organisation (WHO) has stated that OA is one of the ten most disabling diseases that limit movement and physical activity (WHO 2019). It was estimated by the year 2050, at least 130 million individuals in the world would develop OA (Maiese 2016). A recent systematic review of 63 international studies reporting OA prevalence based on MRI has stated that the prevalence of asymptomatic uninjured knees OA was 19%–43% in adults aged over 40 (Culvenor et al. 2019). Furthermore, WHO estimated that 9.6% of male and 18.0% of females aged over 60 years have symptomatic OA (WHO 2019). Vos et al. (2015) estimated the global prevalence of Knee OA 3.8%, ranging from 2.3% in males to 4.5% in females, which was higher in the higher income countries at 7.0%; 4.9% in males and 9.1% in females.

A country-specific prevalence shows that in the United States (US), the high prevalence of knee OA levels in the elderly was associated with the rise of life expectancy and ageing (Wallace et al. 2017). Recently, Cisternas et al. (2016) estimated that 30.8 million adults have osteoarthritis in the US. Furthermore, it was maintained that approximately 2 million individuals under the age of 45 have symptomatic knee osteoarthritis (Deshpande et al. 2016). The prevalence of OA knee in North America was 4.15%; and higher in females (3.5% in males and 5.06% in females) (Vos et al. 2015). In Asia, the prevalence of knee OA was higher in rural areas (13.7%) as compared to in urban areas (6.9%) (Fransen et al. 2011). The previous study maintained that the lifestyle habits in Asian countries could have led to a higher risk for knee OA compared to Europeans and Americans. In India, Venkatachalam et al. (2018) studied the prevalence of symptomatic knee OA among 1986 adult, of which they found that 27.1% had OA of the knee. In Europe, a retrospective cohort study of more than 3 million subjects in the Spanish population found that clinically defined knee OA incidence rates were 6.5/1000 person per year (Prieto-Alhambra et al. 2014). In addition, Arthritis Research UK (2019), estimated 18.2% of individuals aged over 45 years in England, 16.6% in Scotland and 17.2% in Wales have osteoarthritis of the knee.

Pereira et al. (2011) carried out a systematic review of 72 studies to summarise the prevalence and incidence of OA globally. The results showed that the prevalence of radiographic knee OA ranged from 6.3% in Greece, 7.1% in Norway, 15.0% in the Netherlands, and 70.8% in Japan. Furthermore, a longitudinal study was carried out in multiple countries with nationally representative samples of people aged between 18 to 70 years old (Brennan-Olsen et al. 2017). Individuals symptoms and self-reported diagnosis identified the prevalence of knee OA. A country-specific prevalence was presented, in which they found in India, 0.9% among 238 arthritic participants were aged 18-29 years old; this percentage increased with ageing and reached 6.7% in people aged more than 70 years old. While in China, the percentage of knee OA ranged between 0.3% and 5.6% for people aged between 40 and 70 years. However, the study shows that the percentage of arthritis was higher in Ghana and Russia and reached 18.6% and 20.1%, respectively.

The literature shows that knee OA prevalence is high, and it varies between continents and countries. This variation could be due to the methodology used for estimations, in which some studies have used the symptoms and self-reported surveys while others have reported the physician diagnosed radiographic knee OA. Moreover, the variation could be due to each country's local lifestyle, obesity rates, and income (Vos et al. 2015). Nevertheless, OA's prevalence is still increasing, with the increase in OA risk factors, resulting in an increased OA incidence (OARSI 2016). By the year 2030, it is estimated that 67 million adults in the US, aged 18 years and older, will have arthritis, compared with the 52.5 million adults in 2010-2012 (Hootman and Helmick 2006). In the next decades, the proportion of doctor-diagnosed OA is estimated to increase from 26.6% to 29.5%, from 13.8% to 15.7% for the knee (Turkiewicz et al. 2014).

Moreover, the prevalence of doctor-diagnosed osteoarthritis in the Dutch population is expected to increase from 7% in 2011 to 12% in 2040 (National Institute for Public Health and the Environment 2018). However, although studies demonstrated that studying the incidence rate of knee OA could be more accurate in demonstrating the risk of contracting the disease compared to the prevalence (Hennekens et al. 2013; Frérot et al. 2018). This type of research is rarely used in clinical research of knee OA. For example, a recent review by Cui et al. (2020) on the incidence and prevalence of knee OA in population-based studies found that among 88 studies with 10,081,952 participants, only 17 studies have examined the incidence rates, and they were mostly from Europe and North America and one in Japan. The findings from Cui et al. (2020) study found that the knee OA incidence rates were 203 per 10,000 person-years (95% CI, 106_331), which was the highest in Japan with 525 per 10,000 person-years (95% CI, 245_902) and the lowest in Norway with 33 per 10,000 per- son-years (95% CI, 1_113). Nevertheless, the current literature lacks knee OA incidence studies, which is highly significant to ascertain the aetiology and reduce the disease's global burden.

2.3.1.1. Knee OA in Saudi Arabia

In Saudi Arabia, there is a lack of national studies that measure knee OA prevalence; instead, several studies estimate the prevalence according to the region. For instance, in Riyadh, the central region, Al-Arfaj and Al-Boukai (2002) randomly interviewed 300 people visiting primary healthcare centres for various reasons. The results showed that the prevalence of radiographic knee OA was 53.3% in males and 60.9% in females. Recently, the prevalence of MRI diagnosed knee OA in Arar region, a city in the northern region in Saudi Arabia, was 39.75% among 410 participants, of whom 25.6% were below the age of 40 years (Alrowaili 2019), and the prevalence was higher in females compared to males (75.6% and 27.7% respectively).

In Arar, a survey showed that the prevalence of self-reported knee OA among 238 older adults aged 60 years was 24.5% (Alkuwaity et al. 2018). The prevalence was similar in females and males (26.8% and 26.1%, respectively). Interestingly, the BMI findings showed that 66 participants were overweight, and 104 were obese, while only 60 participants were in normal BMI. Alkuwaity et al. (2018) study highlight the association between obesity rates and knee OA prevalence. For instance, a study of the prevalence of knee OA and associated obesity was carried out in Al-Ahsa city in the eastern region (Ismail et al. 2006). The study included 243 participants (72 male and 171 female, aged between 20-80 years) diagnosed with clinically symptomatic and radiographic evidence of knee OA. The findings show that 90.53% of the participants were overweight and obese. This association was found in female more than male (73% and 41.65%, respectively).

However, it is important to point out that the previous studies' prevalence shows that radiographic knee OA was higher than self-reported surveys. This could indicate that Saudi Arabia's population may not be sufficiently aware of knee OA or the presence of asymptomatic OA. For example, a survey of 1052 participants explored knee OA's knowledge among the general population in Aseer region (Mukharrib et al. 2018). The respondents to the self-administered questionnaire, aged between 17 to 80 years old (mean age of 38 ± 12 years old), were recruited from several public areas in the region. The survey included questions about demographics, awareness of knee OA, risk factors, signs and symptoms, disabilities, prevention, and management. The findings show that 89% of the participants had good awareness regarding preventive measures of knee OA and management of knee OA (84.1%). However, the structure of the questions and the full questionnaire was not provided. Only an example of the questionnaire questions was described, such as 'are you aware of knee OA' was given. These types of direct questions may not reflect the knowledge of participants about the disease.

In summary, the prevalence of knee OA worldwide is high, and it is the fifth-ranked disability among all forms of disability-led diseases. In Saudi Arabia, although there are studies that have evaluated the prevalence in different regions, which showed that the prevalence was higher than in other countries in Europe, Asia and the US. This would suggest that there might be lifestyle, genetics and cultural influence on the prevalence of knee OA in Saudi Arabia. However, still, there are no studies at a national level that have measured the prevalence of knee OA nor in the western region of the country. Furthermore, the population awareness of the diseases was only explored in one study. Therefore, considering that the prevalence of knee OA could be higher in the higher income countries, the exact numbers of knee OA individuals in Saudi Arabia could be very high, and the burden of such disease could be higher than in other countries.

2.3.2. The burden of OA

As the global prevalence of knee OA is high, it causes an adverse impact on welfare, economy and resources. For instance, knee OA accounts for approximately 85% of the healthcare costs worldwide (GBD 2017 Disease and Injury Incidence and Prevalence and

Collaborators. 2017). It can lead to several burdens at the individual and socioeconomic levels (Hunter et al. 2014).

The burden of knee OA at the individual level has been directly related to the experienced symptoms, such as the pain and activity limitations that reduced the quality of life and adverse effects on mood, fatigue and sleep (Hawker 2009; Hunter et al. 2014). It may also be accompanied by comorbidities that contribute to the reduced quality of life, such as; obesity, hypertension and high cholesterol levels (Hunter and Bierma-Zeinstra 2019). Moreover, it is maintained that half of all adults with cardiovascular disease or diabetes have arthritis, and most adults with arthritis and cardiovascular disease will have activity limitations (Barbour et al. 2017). This activity limitation and disability might be counteracted by promoting assistive devices such as walking aids and reworking the environment to improve the accessibility for individuals with knee OA in public places and transportation (Palazzo et al. 2016).

Knee OA could also lead to losing productivity, such as the loss of work, sick days, absence, early retirement, income loss and reduction in personal savings, which have led to an increase in the healthcare costs (Li et al. 2006; Hunter and Bierma-Zeinstra 2019). According to Sandell (2012), OA was among the highest causes of work loss that affected over 20 million individuals, costing more than $100 billion annually from the US economy. Kotlarz et al. (2010) stated that individuals with knee OA missed an average of three workdays/ year, which costs the employee $500/ year. Other research suggested that 2% of all sick days were related to knee OA (Hubertsson et al. 2013). The socioeconomic burden of living and managing this condition and its effects on productivity are enormous.

Moreover, OA poses a significant socioeconomic burden, in which more than 1 million osteoarthritic adults in the UK consult their GP each year (Arthritis Research UK 2014). OA's medical care cost in various high-income countries accounts for between 1% and 2.5% of the gross domestic product. In contrast, knee joint replacements accounted for a significant proportion of these healthcare costs (Hunter et al. 2014). The high economic burden of OA was defined in several countries. For example, in the US, the healthcare costs of knee OA were $140 billion, and half the medical costs were attributed to ambulatory care (Murphy et al. 2018). Arthritis was the second among the conditions with high treatment costs, especially if a joint replacement is needed (Torio and Moore 2016). It is estimated that 25% of arthritis-related hospital visits are accounted for OA (The American Academy of Orthopaedic Surgeons 2011).

High direct costs of care of knee OA were attributed to the hospitalisation and surgery rather than the medications, diagnostic procedures and healthcare providers visit (Hunter et al. 2014). In the US, total knee replacement (TKR) for the severe knee OA stage has been performed on 658,000 individuals annually (Bhandari et al. 2012). In Australia, arthritic diseases healthcare costs about $24 billion per year, affecting one in eight adults (Finch et al. 2015). In the UK, Willis (2015) reported that TKR surgeries are increasing in number, in which 80,000 surgeries were performed in 2011, increasing by 3% per year. Therefore, since the knee OA prevalence is increasing, it is expected to increase healthcare costs, which may cause a tremendous economic impact in the future (London et al. 2011). There is a lack of literature on the burden of knee OA in Saudi Arabia; however, the high prevalence of knee OA may suggest similar, high costs of the disease on the country's economy, which could be investigated in future studies.

2.3.3. Management of knee OA:

There is currently no cure for osteoarthritis (Hunter and Bierma-Zeinstra 2019), and a hierarchy of management is recommended for managing knee OA, which begins with pharmacological and conservative modalities and end up with surgery (Bruyère et al. 2016). According to the American College of Rheumatology/Arthritis Foundation guideline, OA's management focuses mainly on impacting the risk factors with conservative modalities (Kolasinski et al. 2020). In mild and moderate knee OA, a combination of pharmacological and conservative approaches may be used in the form of pain killers, patient education, exercises and weight loss (Hochberg et al. 2012). In severe knee OA, if the joint is severely damaged, pain is inevitable, and if other approaches fail, surgical approaches might be suggested according to the individuals' needs (Mcalindon et al. 2014; Yu and Hunter 2015). Effective management of knee OA typically involves a multidisciplinary team of healthcare providers, including general practitioners, rheumatologists, orthopaedic surgeons, physiotherapists and other allied health professionals (Victorian Musculoskeletal Clinical Leadership Group 2018).

2.3.4. Clinical Practice Guidelines for conservative treatments

Conservative management is considered essential and a priority in treating knee OA, as it is relatively low in cost, effective, and has a substantial public health impact (Arden et al. 2018b; Bannuru et al. 2019). Conservative management are non-surgerical interventions, which has several types and forms, such as patient education, exercise, weight loss and walking aids. Many clinical practice guidelines (CPG) exist to facilitate translation of knowledge to healthcare practice and aid the evidence-based clinical decision making in the management of knee OA. These guidelines are listed in Table 3. To improve the quality of care of individuals with knee OA and enhance clinicians' decision-making process, they are encouraged to follow these CPGs (Tittlemier et al. 2020). The guidelines were initially developed mainly by expert opinions, which later changed to rely on research evidence and expert opinions (Dijkers 2013). Thus, CPGs have been influencing clinical practice due to the growing movement toward evidence-based medicine (Altman et al. 2015). The following section reviews the recently published guidelines recommendations for managing knee OA from several organisations. The included CPGs were included if they were written in English and published in the last ten years in order to review and compare the changes in the recommendations. In addition, the CPGs must have included recommendations for conservative interventions in knee OA and a grading system to evaluate the evidence and have been peer-reviewed before publication. As a result, a total of 5 guidelines were reviewed and presented in the following section. A summary of guidelines recommendations can be seen in Table 3 and Table 4.

Table 3 Summary of clinical practice guidelines for conservative interventions

Guideline	Aim	Method	Conservative recommendations	Limitations
European league against rheumatism (2013)	Non-pharmacological management of hip and knee osteoarthritis	Systematic literature search, a consensus of 21 experts (2 nurses, one psychologist, two occupational therapists, three physiotherapists, five rheumatologists, two orthopaedic surgeons, one general practitioner, 2 OA individuals, one clinical epidemiologist and one research fellow)	Assessment: biopsychosocial approach including; physical status, ADL, mood, participation and health education needs Treatment: individualised management plan including core treatments in the form of; patient education, weight loss and exercises Forms of exercise: strength, aerobic and stretch Education: weight loss, increase physical activity, work adjustments and appropriate shoes. Mode of delivery: individual, groups The use of assistive devices such as walking aids	Does not consider other evidence-based interventions in conservative interventions. It does not provide recommendations on what to avoid No recommendations on disseminations into practice It does not describe the type of exercise, frequency or intensity
European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis and Musculoskeletal Diseases (ESCEO) (2019)	Management of knee OA based on algorithm method	GRADE methodology: a systematic literature search and consensus of 18 members including (rheumatologists, specialists in physical medicine and rehabilitation, clinical epidemiologists, endocrinologists, pharmacologists, orthopaedic surgeons, geriatricians, specialists in public health and health economics, research scientists and patient representatives)	Core sets of interventions that involve patient education, weight loss and exercises. Background treatment involves a referral to physical therapists to provide knee braces, insoles, walking aids, thermal agents, manual therapy, patellar taping, aquatic exercise and Tai Chi	Mostly regarding the non-conservative interventions and intended for various location and phenotypes of OA, with a lack of sufficient details on the conservative options. Background conservative

				interventions were not graded with their level of recommendations, as they were only included in the algorithm with a lack of details on their application and quality of evidence It does not describe the type of exercise, frequency or intensity
Osteoarthritis research society international (2019)	Patient-focused treatment recommendations for individuals with knee, hip, and polyarticular osteoarthritis (OA)	Grade methodology: a systematic literature search and consensus between four teams; core expert panel, literature review panel, voting panel and individuals' panel. The voting panel included rheumatology, orthopaedic surgery, primary care, sports medicine, physical therapy, and pharmacology.	Recommendations for assessing OA and associated comorbidities to make an appropriate patient-centred, clinical decision. Core treatments are land-based exercise, mind-body exercise (such as tai chi and yoga), weight management and patient education. Conditionally recommend aquatic exercise, gait aids and self-management program, cognitive behavioural therapy with exercise Strongly recommended against acupuncture, mobilisation, manipulation, brace, therapeutic ultrasound, thermotherapy (hot/ cold), varus/valgus unloading,	It does not describe the type of exercise, frequency or intensity

			massage, wedge insoles, electrical stimulation, Kinesio taping, patellar taping and knee sleeves	
National Institute for Health and Clinical Excellence (2014)	Management of OA	GRADE methodology: Systematic literature searches and multidisciplinary Guideline Development Group (GDG) comprising professional group members and consumer representatives of the main stakeholders, including a project manager, systematic reviewers, health economists and information scientists.	A holistic approach to osteoarthritis assessment and management, including three core treatments for knee OA. **First** is ongoing patient education about their condition, footwear and treatment options that should be patient-centred. **Second** is the active treatment in the form of strengthening and aerobic exercises. **The third** core treatment is interventions for weight loss for overweight individuals Manipulation, stretching exercises, electrotherapy, braces and the use of hot or cold packs are only adjunct to the core treatment	It does not describe the type of exercise, frequency or intensity Individuals.
American College of Rheumatology/Arthritis Foundation (2020)	Managing OA of hip, knee and hand	GRADE methodology: systemic literature search, and comprised of five teams; a Core Leadership Team, a Literature Review Team, an Expert Panel, a Patient Panel and an interprofessional Voting Panel; included rheumatologists, an internist, physical and occupational therapists, and individuals)	<u>Strongly recommended</u> interventions for knee OA are; Exercise, weight-loss, self-management, Tai Chi, Cane and braces <u>Conditionally recommended</u> interventions are; Balance exercise, yoga, cognitive behavioural therapy, Kinesio-tape, acupuncture and thermal intervention	Does not describe the applicability and prioritisation of the interventions and lack guidance with a progressive logical step in the treatment Dissemination of CPG to clinical practice was not addressed

			Modified shoes, wedges, massage, manual therapy and pulsed vibration therapy; were conditionally recommended against, Transcutaneous electrical nerve stimulation (TENS) was strongly not recommended the use for knee OA.	

Table 4 Summary of guidelines conservative management recommendations for managing knee OA

Intervention/CPG	ACR & AF, 2020	OARSI, 2019	NICE, 2014	ESCEO, 2019	EULAR, 2013
Exercise (strength and aerobic)	Strongly recommended	Core treatment	Core treatment	Strongly recommender as a core treatment	Core treatment
Education and self-management	Strongly recommended	Core treatment	Core treatment	Strongly recommender as a core treatment	Core treatment
Weight loss	Strongly recommended	Core treatment	Core treatment	Strongly recommender as a core treatment	Core treatment
Tai Chi	Strongly recommended	Core treatment	Not included	Recommended	Not included
Yoga	Conditionally recommended	Core treatment	Not included	Not included	Not included
Balance exercise	Conditionally recommended	Not included	Not included	Not included	Not included
Acupuncture	Conditionally recommended	Strongly recommended against	Not recommended	Not included	Not included
Thermotherapy	Conditionally recommended	Strongly recommended against	an adjunct	recommended	Not included
Massage	Conditionally recommended against	Strongly recommended against	Not included	Not included	Not included
Manual therapy (manipulation, mobilisation)	Conditionally recommended against	Conditionally recommended against	adjunctive treatment	recommended	Not included
Brace	Strongly recommended	Strongly recommended against	an adjunct	recommended	Not included
Wedges	Conditionally recommended against	Strongly recommended against	an adjunct	Not included	Not included
Walking aids	Strongly recommended		an adjunct	recommended	Not included
TENS	Strongly recommended against	Strongly recommended against	an adjunct	Not included	Not included
Kinesio taping	Conditionally recommended	Strongly recommended against	Not included	Not included	Not included

Patellar taping		Strongly recommended against	Not included	recommended	Not included
Cognitive behavioural therapy	Conditionally recommended	In favour	Not included	Not included	Not included
Stretching	Not included	Not included	an adjunct	Not included	Not included
Aquatic exercise	Not included	Conditionally recommended	Not included	Recommended	Not included
Therapeutic ultrasound	Not included	Strongly recommended against	Not included	Not included	Not included

There is a consensus in most of the CPG on including therapeutic exercises, patient education and weight loss as a core treatment for knee OA. These core interventions were recognised with the highest quality of evidence, and they are safe to apply to all individuals. While several interventions such as manual therapy, massage, braces, acupuncture, thermotherapy, braces, Kinesio taping and electrotherapy were recommended in older guidelines, these were recently not recommended with the rise of new evidence (Kolasinski et al. 2020). Therefore, clinicians are encouraged to be updated with the current evidence and avoid using controversial interventions. Therapeutic exercises that aim to improve muscle strength, aerobic capacity, balance and flexibility would improve the individuals' pain, functional activity and quality of life. Therefore, it would result in receiving the enormous benefits of physical activity enablement that were discussed in section 2.5. Background on Physical Fitness and Physical Activity. However, despite their high quality of evidence, CPGs have their limitations and weaknesses in recommendations which were discussed in the following section.

2.3.4.1. Applicability and dissemination limitations of the guidelines

Like any other study, the guidelines are exposed to methodological limitations, and they should be assessed for their methodological quality of evidence, their applicability, and their dissemination to clinicians. Hence, assessment of the guidelines could be carried out with the Appraisal of Guidelines Research and Evaluation (AGREE II) tool (Brouwers et al. 2010). For instance, the literature shows that most of the guidelines achieved the lowest scores in the applicability domain, which is concerned with barriers and facilitators to implementation, strategies to improve, and resource implications of applying the guideline (Appendix Q). This would suggest that these CPGs may lack information on the barriers to their application, the implication of the recommendations and tools to disseminate the guidelines into clinical practice. Consequently, though evidence shows that treatment outcome improves when the guidelines are followed (Dziedzic et al. 2014), the utilisation and awareness of the evidence-based practice and CPGs have not met in some countries (da Costa et al. 2017; Holden et al. 2018), indicating a gap between clinicians and the evidence.

For instance, a recent study in Belgium confirmed the previous statement regarding low adherence to the guidelines (Spitaels et al. 2019). The study involved 235 individuals with knee OA who completed a survey to recall their physicians and physiotherapists' treatment. The results showed only 24.3% received education about weight loss, and 22.6 were educated about managing loads at the knee joint. In addition, less than half of the participants reported they were educated about the importance of exercise (43%), and only 40.7% reported that they were referred to physiotherapy. Interestingly, the majority of physiotherapists (83.6%) administered strengthening and functional exercises, whilst aerobic exercises and physical activity advice were not reported. However, the individuals reported questionnaires are based on their ability to remember and recall the treatments they received in the last year, which could be inaccurate since they may forget what they have been offered.

Nevertheless, another investigation by the same author (Spitaels et al. 2017) measured guideline adherence among 284 physiotherapists, which demonstrated excellent adherence to some guidelines. The results showed that more than 80% had offered patient education about the importance of exercise and tailored strengthening and functional exercises. However, the study found that there was a lack of patient education about weight loss and self-management, in addition to the application of controversial or non recommended interventions such as massage (49%) and thermotherapy (24%), which would suggest a lack of awareness among physiotherapists regards recent updates in the guidelines.

Several other studies in many countries have demonstrated physiotherapists' lack of adherence to OA management guidelines. For instance, in Guyana, Ferreira (2017) found that physiotherapists had minimal knowledge of evidence-based practice and clinical guidelines. Likewise, in Norway, Jamtvedt et al. (2008) measured physiotherapy performance in individuals with knee OA. A total of 297 physiotherapists participated in the study and reported their management of one patient for 12 sessions, which was then compared to CPGs. The results showed that 98% had used exercise and 68% used patient education, which is recommended in the CPGs and considered a core treatment. Surprisingly, 35% of physiotherapists have used acupuncture, low-level laser therapy or TENS, which had a moderate quality of evidence at the time of the study. Moreover, 42%

did not provide advice for weight loss for obese individuals, while there were trends in using treatment modalities with low or without evidence such as traction (46%), massage (54%), stretching (46%) and tape (3%). This could indicate that the implementation of guidelines is out of their scope of practice or a lack of knowledge and cultural barriers to guideline implementation.

There are few studies in Saudi Arabia exploring the physiotherapy evidence-based practice of knee OA and guidelines implementation. The limited adherence to CPGs discussed in this section may indicate a similar trend in physiotherapy management for knee OA in Saudi Arabia. A recent study in Saudi Arabia by Alshehri et al. (2017) explored physiotherapists' behaviour, attitudes, awareness, knowledge and barriers to evidence-based practice. A convenience sample of 376 physiotherapists who participated in an online survey consisted of 14 closed questions based on similar evidence-based practice studies. Recruitment was carried out through social media platforms (Facebook, Twitter, Instagram, WhatsApp and e-mail). Moreover, the questionnaire included seven main components; demographics, behaviour, attitudes, awareness, knowledge, formal training and barriers.

Among 376 participants, 66.2% had a bachelor's degree, 19.9% master's and 8.2% PhD degree. Most of the participants were working at MOH hospitals (40.7%), while the others are scattered between private (16.5%), other health facilities (26.6) and 16.2% at academic settings. The results show that the majority of participated physiotherapists are making their clinical decision 'always or often' based on their personal experience (75.6%), books (59.9%) and research studies (56.9%). Moreover, 95% of participants agreed that reading research was necessary for their practice and interventions should be supported by evidence (81.4%). Interestingly, although they understood the term 'systematic review' (64.9%) and randomised controlled trials (60.6%), approximately 23.1% of participants never heard of the term evidence-based practice, while 40.2% never heard the term 'PICO', which is a basic research term. Several barriers to evidence-based practice were identified, such as; insufficient teaching (43.1%), lack of research knowledge and skills (36.4%), lack of funding and resources (35.7%), lack of support and encouragement (30.6%), lack of interest (23.4%) and lack of time (22.8%). Overall, there was a positive attitude towards an evidence-based practice that was mostly associated with education level ($P<0.001$).

In general, the adherence to CPGs and evidence-based practice may vary between countries, while noting that there is the frequent use of strengthening exercises as a leading intervention (Appendix R). There are minimal studies that reported providing patient education about weight loss, the importance of physical activity, aerobic exercises, while there is a trend towards using non-evidence-based interventions. This could mean that both globally and in Saudi Arabia, physiotherapists may not be sufficiently aware of the guidelines, or they might have social or resources barriers to its implementations. Furthermore, the lack of adherence could be due to limitations in guidelines such as the 'applicability' and dissemination into clinical practice. Furthermore, while evidence suggests a tailored, individuals' specific treatment plan, many physiotherapists do not consider individual characteristics, pain, and needs in the treatment plan (Jamtvedt et al. 2010). Though guidelines recommend focusing on self-treatment and patient-driven treatments rather than on passive therapies delivered by clinicians (Hinman et al. 2016), many therapists provide passive treatments (Ferreira 2017).

2.3.4.2. Limitations of the recommendations in the current knee osteoarthritis guidelines

There are several limitations addressed in the guidelines regarding their recommendations. For instance, most CPGs do not describe the interventions' prioritisation and which OA phenotype to apply these recommendations to. In addition, the guidelines do not provide exercise prescription as a description of the type of exercise, frequency or intensity. To elaborate, exercise prescription is a specific plan of fitness-related activities designed for a specified purpose (American College of Sports Medicine 2017). According to ACSM (2017), exercise prescription is characterised by the FITT principle for Frequency, Intensity, Time, and Type in order to improve or maintain physical fitness and health. The FITT principle may serve as guidance for providing therapeutic exercise prescription for individuals with knee OA. However, since the clinical practice guidelines do not provide details on exercise prescription, this could lead to treatment being led by personal clinicians' choices, and clinicians may not be able to provide evidence-based therapeutic exercise for knee OA, which may affect the quality of the outcome of treatment. Moreover, the guidelines recommend mainly strengthening and aerobic exercises, with the lack of detailed description of the other types or forms of exercise. This may suggest that other forms of exercise are not essential, and the other components of PF such as balance and flexibility may be overlooked in the treatment plan of knee OA.

2.3.4.3. Summary of clinical practice guidelines

Clinical practice guidelines are the tools that transfer knowledge of evidence-based practice to healthcare professionals, and they were developed under rigorous and systematic approaches, using the highest quality of evidence available. However, the literature shows that globally, their applicability and dissemination into clinical practice is still challenging. Moreover, most guidelines do not provide exercise prescription recommendations as frequency, intensity, type and time. Consequently, it may not effectively guide the clinicians in designing a treatment plan for individuals with knee OA. Nonetheless, it is unknown if therapeutic exercise studies that are included in the guidelines are not adequately providing details on exercise prescription; thus, the guidelines are not including them. Therefore, there is evidently a need to review therapeutic exercise studies to understand current exercise prescription evidence and subsequent effectiveness in managing knee OA. Hence, a review of systematic reviews on the benefits of different therapeutic exercise forms for knee OA were presented in the following section.

2.4. Therapeutic Exercise

Therapeutic exercises are designed and prescribed by clinicians to achieve specific therapeutic goals (Holden et al. 2020). They are established as a critical element and one of the core treatments of knee OA (National Institute for Health and Clinical Excellence 2014). Therapeutic exercises have many forms such as strengthening, aerobic, flexibility, mind-body (e.g. yoga, Tai Chi), aquatic and walking exercises. Studies show that exercise may not affect the damaged joint structure but rather on the individuals' pain and functional status (Van Ginckel et al. 2019). The literature shows that exercise has significant benefits on improving pain, balance, strength, aerobic capacity, and knee OA individuals' function, irrespective of disease severity, age, comorbidity, pain severity or disability (Arden et al. 2019). Exercise is believed to play an essential role in delaying OA initiation and progression as it may modify joint biomechanics that leads to a decreased joint loading and localised stress in the articular cartilage (Fransen et al. 2015a). Furthermore, aerobic exercises that improve cardiorespiratory endurance and mind-body exercise that improve mindfulness/relaxation are also an effective treatment for knee OA. Exercises significantly affect weight loss, which is a significant risk factor for knee OA (Hunter and Bierma-Zeinstra 2019; Westerterp 2019).

The literature search resulted in 8 systematic reviews evaluating the effectiveness of therapeutic exercise in individuals with knee OA (Table 5). Five systematic reviews included various forms of therapeutic exercises, two included strengthening exercise alone, and one on aquatic exercise. Six reviews included a follow up ranging from immediately after treatment and up to 28 months, and the outcome measures included in all the studies were pain, function and quality of life. Five systematic reviews evaluated multimodal exercise, including strengthening, aerobic, Tai-chi, balance, flexibility and aquatic exercises (Silva et al. 2012; Rogers and Semple 2013; Tanaka et al. 2013; Uthman et al. 2013; Goh et al. 2019). In Rogers and Semple (2013) study, a total of 91 clinical trials with moderate quality showed a significant improvement in pain and function. Similarly, Goh et al. (2019) recently reviewed 103 randomised controlled trials of 9134 participants with knee OA. The study results showed that aerobic and mind-body exercise was more beneficial in improving pain and function with large effect size while strengthening and flexibility exercise showed a moderate effect size on improvement on pain, function and quality of life.

Moreover, Uthman et al. (2013) carried out a systematic review and meta-analysis to study the effectiveness of exercise compared to no exercise in knee OA. Sixty trials were included involving 8218 individuals who underwent 12 forms of therapeutic exercises. The results showed a significant improvement in pain and function from aerobic, strengthening and flexibility exercises with a superior effect with a combination of the several forms of exercise at four weeks and up to 79 weeks follow up. In Tanaka et al's (2013) systematic review and meta-analysis of 8 randomised controlled trials study exploring the effect of strengthening and aerobic exercise on pain, the results were consistent with the literature, showing that strengthening and aerobic exercises were equally effective in reducing the pain of knee OA individuals. Therapeutic exercises also have a significant effect on improving balance. For instance, Silva et al. (2012) carried out a systematic review of nine randomised controlled trial evaluating the effect of several forms of therapeutic exercise on balance in females with knee OA. The studies included aerobic exercise, strength training, Tai Chi, hydrotherapy, vibrating platform exercise, balance exercises and educational exercises. The results demonstrated that therapeutic exercises improved balance, pain, function and quality of life of females with knee OA, with a superior effect of strength training compared to other forms of exercise.

Three systematic reviews evaluated the effectiveness of only one form of therapeutic exercise: strengthening or aquatic. For instance, Fransen et al. (2015b) carried out a Cochrane systematic review of randomised clinical trials comparing land-based strengthening exercise with a non-exercise control to evaluate the benefits of exercise for knee OA immediately after treatment and 2-6 months after termination of treatment. Fifty-four trials were included, which show that strengthening exercise significantly improved pain, quality of life and physical function in knee OA immediately after treatment. Whereas 12 trials showed a significant reduction of pain and physical function improvement after 2-month to 6-month post-treatment. Consistent with the previous literature, Zacharias et al. (2014) reviewed the effectiveness of strengthening exercise in 40 randomised controlled trials. The results showed that high quality of evidence demonstrated the significant short-term effect of low-intensity strengthening exercise compared to control, while the moderate quality of evidence of high-intensity strengthening exercise showed a significant short-term effect on muscle strength. A systematic review and meta-analysis of the effect of aquatic therapeutic exercise on pain, range of motion, self-reported function and quality of life (Bartholdy et al. 2017). The study included 11 randomised controlled trial involving 1092 individuals with knee OA. The results show a significant improvement in function and range of motion, but no improvement in the quality of life or muscle strength were found.

Nevertheless, the review of the eight systematic reviews showed that they had several limitations, such as the variety of instruments used for measuring the outcome and the duration of interventions, and small sample size (Silva et al. 2012; Rogers and Semple 2013; Tanaka et al. 2013; Bartholdy et al. 2017). Moreover, the included studies within these systematic reviews did not provide a description of exercise prescription such as intensity, frequency and technique, and there was an overlap between forms of exercise. This may vary significantly between studies and could confuse physiotherapists if not recognized, and an accurate judgment on the most beneficial form of therapeutic exercises may be unachievable. Moreover, the literature shows that due to limitations of therapeutic exercise studies in the form of lack of exercise details and overlap between the different forms, there is a wide range of effect sizes and mode, intensity, and frequency of intervention play a large role in pain relief (Susko and Kelley Fitzgerald 2013; Bandak et al. 2019). Moreover, this lack of details on exercise could also indicate that the other components of PF such as balance, flexibility and body composition may be overlooked. Finally, the eight systematic reviews included studies with low to moderate quality. Therefore, conclusions based on these results should be made with caution due to this lack of information and inconsistency of interventions and measures.

2.4.1. Summary

Therapeutic exercise may benefit people with OA, and it could reduce the pain and improve aerobic capacity, muscle strength, balance, flexibility, which enable the OA individual to be more physically active (Felson and Chaisson 1997; Miller et al. 2013; Liow et al. 2017). Evidence for therapeutic exercise has been presented from 8 systematic reviews, which included 376 individual studies. Overall, there was an overwhelming consensus on the importance of therapeutic exercise for managing knee OA regardless of the form applied.

Evidence shows a significant improvement in pain, function and quality of life in individuals with knee OA, which could be attributed to improved physical fitness components such as aerobic capacity and muscle strength (Hunter and Bierma-Zeinstra 2019). However, since most of the included studies focus on strengthening and aerobic exercises in addition to lack of details on exercise prescription such the frequency, intensity, type and time, it does not address other PF components such as balance, flexibility and body composition, which may not be included in the treatment plan. Consequently, there is a need to have a comprehensive assessment of PF components, including aerobic capacity, muscle fitness, body composition, flexibility and balance, in order to establish evidence of affected PF components in knee OA individuals that could be targeted for treatment.

Table 5 Summary of the review of therapeutic exercise systematic reviews

Author	Type of study, Number of studies and number of participants included	Form of exercise	Outcome	Results	Limitations
Fransen et al. (2015b)	A Cochrane systematic review of 54 RCT (8523 participants)	Land-based therapeutic exercises such as strength, aerobic, balance and aquatic.	Variety of Self-reported Pain, physical function and quality of life scales	Exercise significantly reduced pain (standardised mean difference (SMD)= 0.49, 95% CI= 0.39 to -0.59), physical function (SMD= 0.52, 95% CI= 0.39 to -0.64), and quality of life (SMD= 0.28, 95% CI= 0.15 to 0.40) immediately after treatment. After two and six months, pain was significantly reduced (SMD= 0.24, 95% CI= 0.35 to -0.14, and physical function (SMD= 0.15, 95% CI= 0.26 to -0.04).	The study included moderate to high-quality evidence. However, there was considerable variability in the included studies. For instance, a wide range of therapeutic exercise programs was assessed with varied modes, intensities, duration, and exercises frequency. Therefore, recommendations on the specific exercise parameters cannot be concluded from this study.
Rogers and Semple (2013)	A systematic review of 91 RCT	Therapeutic exercises including; Strength, balance, aerobic, tai-chi, aquatic exercise and yoga	Variety of self-reported and performance-based tests on Pain, physical function, muscle strength and balance	Therapeutic strengthening, aquatic, aerobic, balance, tai-chi and yoga exercises are beneficial for improving pain, function, balance and muscle strength in individuals with knee OA	The study had a weak methodology as it did not describe their study selection or inclusion criteria, nor there were details of the quality and risk of bias assessment of the included studies. The authors thematically analysed and presented the studies, which had a wide range of differences in the population, designs,

					interventions and outcome measures. Therefore, although ascertain conclusion could be challenged to be made based on their methodology. However, the results suggest the benefits of different modes and forms of therapeutic exercises, which could be used with knee OA individuals.
Goh et al. (2019)	Systematic review and meta-analysis of 103 RCT (9134 participants)	Therapeutic exercises including; Aerobic, mind-body, strengthening, flexibility/skill, or mixed vs usual care	Self-reported pain, function, and quality of life. In addition to performance-based measures for walking speed, range of motion and strength.	The effect of exercises varies according to the type of exercise: Aerobic and Mind-body exercises were most beneficial for Pain (Aerobic Effect Size= 1.11, 95% CI= 0.69, 1.54; mind-body ES= 1.11, CI= 0.63, 1.59), Performance (Aerobic ES= 1.05, CI= 0.63, 1.48) and Function (mind-body ES= 0.81, CI= 0.27, 1.36). Strengthening and flexibility exercises resulted in moderate improvement pain (strengthening ES= 0.73, CI= 0.49, 0.98; flexibility ES= 0.65, CI= 0.29, 1.00), function (strengthening ES= 0.76, CI= 0.48, 1.03; flexibility ES= 0.68, CI= 0.28, 1.09), performance (strengthening ES= 0.55, CI= 0.32, 0.78; flexibility ES= 0.68, CI= 0.34, 1.03). Mixed exercises are the least effective, with an effect size ranged	The study had several limitations: the lack of bias assessment, limited description of exercise intensity, frequency, and type in the included studies. The forms of the exercise varied considerably, with an acknowledged overlap between different forms of exercise. The control group was not defined clearly, as the author acknowledged the usual care to include treatments provided by the physicians, which may cause uncertainty in the results since their treatments are unknown.

				between 0.19 to 0.48 in all outcomes.	
Tanaka et al. (2013)	A systematic review of 8 RCT	Strengthening and aerobic exercise compared to non-exercise control	Self-reported pain scales	The exercise was statistically significantly better than no exercise at reducing pain for individuals with knee osteoarthritis (SMD -0.94, 95% CI -1.31 to -0.57). Strengthening and aerobic exercises were equally effective in reducing pain and function of knee OA individuals.	A wide range of variability in the exercise's parameters of the included studies with a lack of description of exercise intensity, frequency and type. Moreover, Low to moderate quality of included studies and they included studies with low, medium, and high risk of bias. In addition to an acknowledged publication bias.
Silva et al. (2012)	A systematic review of 9 RCT	Therapeutic exercises to improve balance including; Aerobic exercise and strength training, Tai Chi, hydrotherapy, vibrating platform exercise, balance exercises and educational exercise	Primary: performance-based Balance tests. Secondary: self-reported pain, function and quality of life.	Therapeutic exercises improved the balance, pain, function and quality of life of females with knee OA	Although the review included eight high-quality studies, the intervention methods and duration varied, and various instruments were used to assess pain and balance. Therefore, a conclusion could not be made based on these variations.
Bartholdy et al. (2017)	A systematic review and meta-analysis of 45 RCT (4699 participants)	Therapeutic strengthening Exercises vs non-exercise control	Self-reported pain, function and disability. Performance-based muscle Strength	Significant improvement in strength (SMD= 0.59, 95% CI= 0.39 to 0.75), pain, (SMD= 0.57, 95% CI=0.42 to 0.73), Function (SMD= 0.56, 95% CI= 0.39 to 0.73).	A small sample size of included studies with moderate to high risk of bias. Moreover, intervention duration, frequency, dose, intensity, exercise selection, and adherence were varied among studies.
Zacharias et al. (2014)	A systematic review and meta-analysis of 40 RCT	Therapeutic exercise including; aerobic, hydrotherapy, resistance and multimodal exercises vs usual care, an alternate	Measures of muscle strength or indicators of muscle strength (e.g., cross-sectional	Significant short-term effect of low intensity strengthening exercise compared to control in knee extension (SMD= 0.47, 95% CI=	The included studies had low to high quality with moderate to high risk of bias. In addition, there was a lack of description of exercise intensity, frequency and type in several studies,

		program with or without exercise.	area or muscle volume)	0.29, 0.66) and flexion strength (SMD= 0.74, 95% C= 0.56, 0.92). High intensity strengthening exercise showed also a significant short-term effect on muscle strength (SMD= 0.76, 95% CI= 0.47, 1.06) Low quality of evidence and inability for meta-analysis were found in the other forms of therapeutic exercises.	with a variety of assessment tools and exercises forms. Hence, although the study indicated a significant superior effect of strengthening exercise compared to controls. However, conclusions could not be made based on these limitations and variations.
Uthman et al. (2013)	A systematic review and meta-analysis of 60 RCT (8218 participants)	Comparing between different forms of therapeutic exercise, including; strengthening, aerobic, flexibility and aquatic, versus non-exercise control	Self-reported pain and function	A significant improvement in pain (SMD= 2.03, 95% CI= 2.82 to −1.26, large effect size) and function (SMD= 1.32, 95% CI= 2.44 to −0.21, medium effect size) from aerobic, strengthening and flexibility exercises. No significant difference in the effect between different types of exercise interventions on pain and function. However, a superior effect with a combination of the several forms of exercise was found.	The included studies had a low to moderate risk of bias. Several included studies had a long follow-up, which could have led to heterogeneity, and it may affect the outcome of the meta-analysis. Moreover, there was a wide range of variability in the exercise's parameters of the included studies with a lack of description of exercise intensity, frequency and type.

2.5. Background on Physical Fitness and Physical Activity

The terms “physical activity”, “exercise” and “physical fitness” are often used interchangeably by researchers and professionals (US Department of Defense 2004). Although they are closely related, they should not be treated as synonyms (Martínez-Vizcaíno and Sánchez-López 2008). The definition of PF has evolved several times in the last decade in order to meet the development in the environment and the component of physical fitness (Pate 1988; Paoli and Bianco 2015). The most commonly used definition is that PF is ‘a set of attributes that people have or achieve relating to their ability to perform physical activity’ (American College of Sports Medicine 2017). While the term exercise refers to a planned, structured, repetitive and intentional movement intended to improve or maintain physical fitness, and it is considered a subcategory of PA (Corbin et al. 2000). On the other hand, the adapted definition of PA is every body movement, produced by skeletal muscles and leads to energy expenditure (Bouchard and Stephens 1994). Corbin et al. (2000) simplified the difference between PA and PF by categorising the terms into product and process. The product refers to ‘states of being’ or the outcome such as; fitness and health, whereas the process relates to lifestyle and behaviours such as; PA and exercise.

2.5.1. Physical fitness concept

Physical fitness has two categories that a person needs to work on to achieve an overall good total PF (Caspersen et al. 1985; American college of sports medicine, 2017). **First**, the health-related fitness category includes the PF components linked to good health, such as; body composition, cardiovascular fitness, flexibility, muscle endurance, and strength (Corbin et al. 2000; American College of Sports Medicine 2017). The other category of PF is skill-related, which associated with enhanced motor skills and sports performance (Corbin et al. 2000; American College of Sports Medicine 2017). Good health-related fitness is associated with improved quality of life and reduced risk of illness (Corbin et al. 2000). In particular, health-related PF is considered as an essential health status indicator, which will reduce the risk of developing metabolic diseases, obesity, cardiovascular and musculoskeletal complications (Anderson and Felson 1988). For any research evaluating PF in people with OA, it would need to include all these components in order to obtain a complete picture of their PF levels that could be targeted for management (American College of Sports Medicine 2017).

On the other hand, skill-related PF has an indirect connection with health; instead, it is linked with sports performance (American College of Sports Medicine 2017). However, it is unclear if health-related or skill-related fitness is more important to people with disabilities as some of the skill-related PF components could be health-related, especially with knee OA individuals. For instance, considering the evidence of affected balance associated with knee OA (Hatfield et al. 2015) and the high incidence of falls in individuals with knee OA (Hunter and Bierma-Zeinstra 2019). Consequently, individuals with knee OA may receive balance training as a critical PF component that could be included as a health goal to improve individuals' independence.

Physical fitness components are associated with improved quality of life and reduced risk of illness (Corbin et al. 2000). The importance of PF to health has led to increasing the value of assessment of PF. Hence, the ACSM (ACSM, 2008) discussed several reasons to assess PF such as; 1) to educate individuals in order to optimise their health, 2) development of individualised exercise programmes to include all components of PF, 3) evaluation of treatment progress, 4) establishing fitness and treatment goals. Moreover, the ACSM suggests that a comprehensive fitness evaluation must include all the components of PF (2017), which are central in setting the treatment goals and monitoring the individuals through a wealth of information on their health and functional status. Each of these components were discussed with regard to their definition, measurement options and their values in individuals with knee OA in Physical fitness and physical activity in knee OA section (Chapter 2.6).

2.5.2. Physical activity concept

Physical activity is a health-related behaviour that contributes to PF status (Caspersen et al. 1985) or is the outcome of good PF (Chen et al. 2018). It has several characteristics or variables that are used to describe the PA pattern, such as the type, frequency, duration and intensity (Corbin et al. 2000). Moreover, the World Health Organisation (WHO 2018) have used other characteristics to describe patterns of PA, such as the context, mode, intensity, frequency and duration of PA. The context refers to the purpose of doing the activity, which has four main domains; 1) leisure time, sport or recreation, 2) occupation, 3) transportation, and 4) others like; household or religion (Rausch Osthoff et al. 2018). The mode is the type of PA, categorised into several groups, such as; non-weight bearing or weight-bearing, aerobic or anaerobic, continuous or intermittent (Corbin et al. 2000; World Health Organization 2010). Moreover, frequency refers to the number of repetitions or the number of days per week. Duration is the amount of time in minutes that has been spent on PA. Intensity is defined as the amount of effort required to perform the activity. It is usually considered light, moderate or vigorous (American College of Sports Medicine 2017).

The benefits of PA and recommendations for the amount and type of PA are well documented in the literature. Regular PA has numerous benefits on the various body systems (World Health Organization 2010; Rausch Osthoff et al. 2018). Specifically, the cardiovascular system, musculoskeletal system and mental health, while also reducing the risk of coronary heart diseases, hypertension, stroke and many other diseases. A considerable amount of literature had been published on the health benefits of regular PA. There is a consensus in the literature on the health benefits of PA and its effects on the quality of life, countries' economies, and society.

A sedentary lifestyle and the lack of PA are significant risk factors for developing chronic diseases such as cardiovascular and musculoskeletal diseases (Warburton et al. 2006). In recent decades, physical inactivity has caused significant health challenges that have led to mortality (Holm et al. 2015). Previous studies have shown that individuals with chronic musculoskeletal pain tend to have low PF and rarely engage in PA (Kamada et al. 2014). Therefore, better general health is strongly associated with enhanced PF, specifically cardiorespiratory fitness and muscle strength (Holm et al. 2015). Moseng et al. (2014) suggested that the involvement of PF exercises in the treatment plan for several musculoskeletal diseases seems to be an effective option for reducing the symptoms and improving the quality of life. However, increased PA level is also a risk factor for developing musculoskeletal diseases. According to Lefèvre-Colau et al. (2016), an increase in PA might lead to musculoskeletal complications due to excessive and accelerated wear and tear' of the joints; therefore, people may follow a balanced lifestyle to maintain their health without causing any further disability.

2.5.3. Relationship between PF components and PA

The relationship between PA and PF components has been considerably recognised in the literature. According to Blair et al. (1989), the relationship between PA and PF is interchangeable, in which PA is a determinant of PF level, and similarly, PF can also be a determinant of PA level. Blair et al. (2001) recommended that people become more active initially rather than fit since the latter will be achieved through activity. However, other scholars advocate that PF is an enabling factor for PA, which provides the physical foundation to engage in physical activities (American College of Sports Medicine 2017; Chen et al. 2018). Physical activity and physical fitness are mutually associated as they enhance one another; ideally, there is a linear relationship between the two terms; for instance, evidence suggests that a higher level of PA (especially moderate to vigorous activities) were directly related to better PF (Cohen et al. 2014; Arena et al. 2016). Conversely, PF components such as; obesity and low cardiovascular fitness were associated with a lower PA level (Erwin and Castelli 2008; Lee et al. 2012; Fang et al. 2017a).

Nevertheless, the relationship between PA and PF components has been shown to be weak or moderate and, in some studies, is not significant. For instance, McDonald et al. (2011) examined the age-related differences in older adults' flexibility aged 55–86 years with various physical activity levels. Hip flexion and shoulder abduction were assessed in 436 individuals, in addition to the Minnesota Leisure-Time Physical Activity Questionnaire. The multiple regression analysis results showed that flexibility was affected by age, not by PA levels, suggesting that no relationship exists between PA and flexibility. In contrast, the relationship between PA and muscular strength were found in Cooper et al. (2017) and (Celis-Morales et al. 2017) studies. However, this may be a weak relationship, according to Leblanc et al. (2015), who examined the relationship between objective and self-report measures of PA and muscle strength. The study involved 412 health participants aged between 20 to 91 years old who underwent a muscle strength assessment with an isokinetic dynamometer in addition to the PA measures. The multiple regression analysis showed strong correlations between muscle strength and age, gender and BMI, but a weaker correlation with PA levels. Although they used valid and reliable tools to measure PA and muscle strength; however, the age spectrum of the participants may play a role in the variation of the results.

Furthermore, since PF could relate to PA patterns, current PA guidelines consider PF an alternate PA measure (Myers et al. 2004). However, there have been arguments as to whether PA patterns could determine PF level and, therefore, its inverse association with mortality, or whether PF level predicts mortality independently from activity pattern (Blair and Jackson 2001; Williams 2001). Myers et al. (2004) compared PF versus PA's contribution to predicting all causes of mortality of 842 males. The results show that low PF and PA were both associated with higher mortality risk in men while noting that PF strongly predicted mortality compared to PA. However, the findings may be limited to males, and the subjectivity of PA questionnaires may be influenced by the participants' recall ability. Despite this, the study may indicate that PF could predict mortality separately from PA.

In a more recent study, Stathokostas et al. (2015) examined the influence of aerobic capacity (a component of PF) and sedentary behaviour on chronic diseases and body composition in older adults. The study involved 292 community-dwelling male and female who underwent maximal treadmill testing and completed questionnaires relating to their leisure-time physical activity, sedentary time, and health. The results showed that aerobic capacity had a stronger prediction of several chronic conditions and BMI than total physical activity. In particular, participants with a higher aerobic capacity had fewer chronic conditions and a lower BMI. In contrast, the total physical activity levels and sedentary time did not result in such an association. However, the study sample may not represent the aged population, as they included only healthy and independently living people. Furthermore, the methods used to assess PA levels were based on the questionnaires' subjective measures, which may be subjected to recall limitation and could lead to overestimation or underestimation of PA (Westerterp 2009; Strath et al. 2013). Furthermore, the maximal treadmill test used to measure aerobic capacity has been argued in the literature to be invalid and unsafe for older individuals, which may result in underestimation of aerobic capacity (Philbin et al. 1995b; American College of Sports Medicine 2017).

Clearly, there is a controversy regarding the relationship between PF components and PA. The previous studies may suggest that PF components measurements could not be used as an indication of PA, but instead, they are an enabling element for PA. Hence, the literature would suggest that regardless of their interchangeable relationship, both PF and PA need to be considered in the current study in order to obtain a comprehensive picture of the individuals' health and function.

2.5.4. Relationship between PF, PA and knee OA

The relationship between PF components and PA in individuals with knee OA could be in the form of a cycle linking OA with associated disabilities such as activity limitation and non-communicable diseases (Felson and Chaisson 1997; Miller et al. 2013; Liow et al. 2017) (Figure 2). These disabilities interact in a continuous cycle that affects the well-being, quality of life and independence of the OA individuals, and it may contribute to reduced healthcare outcome if not interrupted (Osteoarthritis Action Alliance 2012). This cycle could be started in multiple steps, levels or reasons. To elaborate, as discussed previously that knee OA is a whole-body disease (American College of Rheumatology 2019), and PF components and PA may have a linear relationship as they affect and interact with each other. Consequently, if one component of PF is affected, it could lead to changes in the other components and the individuals' PA.

2.5.4.1. Theories

Since knee OA is a whole-body disease associated with a large number of disabilities, it may require a holistic view of the diagnosis of knee OA individuals. This may be achievable with the views of the International Classification of Functioning, Disability and Health (ICF) (World Health Organization 2001), which consider multidimensional measures, including biopsychosocial approaches in the diagnosis. The ICF relies on the dynamic interaction between its two parts; Functioning and Disability, which involves body structure and activity participation; and Contextual Factors that include environmental and personal factors (World Health Organization 2001). As discussed earlier, PF components and PA may have an interchangeable relationship, and PF is the enabling elements for PA; this would agree with the ICF's views regarding the interaction between body structure and function. Hence, the assessment of individuals with knee OA may need to include factors derived across the ICF dimensions in order to identify the most important measures for enabling OA individuals to self-manage and cope with their most valued functional goals.

2.5.4.2. Knee OA cycle

It has been reported that the most significant symptoms in individuals with knee OA are knee pain (Arden et al. 2018b), which may start the continuous cycle (Figure 2). The OA pain could be a barrier that leads to physical activity limitation (Gay et al. 2018; Coste et al.

2019). Physical inactivity, in turn, could lead to an increase in weight, reduced muscle strength and aerobic capacity, which in itself is also a risk factor for knee OA (Myers et al. 2015; Osteoarthritis Action Alliance 2019). Therefore, physical inactivity and reduced PF components such as; muscle strength and aerobic capacity could result in weight gain and obesity (British Lung Foundation 2017; Coste et al. 2019).

Consequently, overweight and obesity would place extra biomechanical stress on knee joints that lead to an increase in OA development and increase the risk and complications of other chronic conditions (i.e., diabetes, cardiovascular diseases) (Parkinson et al. 2017; Cleveland et al. 2019). However, it is essential to consider that each level or step is considered a risk factor or an outcome for knee OA (Chaganti and Lane 2011; Suri et al. 2012; Arden et al. 2018a). Thus, it has been debated which of those disabilities could lead to knee OA and starts the continuous cycle (Alnahdi et al. 2012; Osteoarthritis Action Alliance 2012).

Nevertheless, the cycle may not be interrupted unless pain, PF components and physical inactivity are targeted for treatment (Figure 1). Hence, physical activity promotion and conservative interventions such as therapeutic exercises were recognised as the most effective means for managing the symptoms and preventing or delaying the progression of OA (Brosseau et al. 2014; Bannuru et al. 2019). However, due to lack of comprehensive evidence of PF and PA in knee OA, which may capture a spectrum of ICF dimensions that may result in an implementation of these components into the management of knee OA. Therefore, the following sections are reviews of studies on PF and PA in individuals with knee OA.

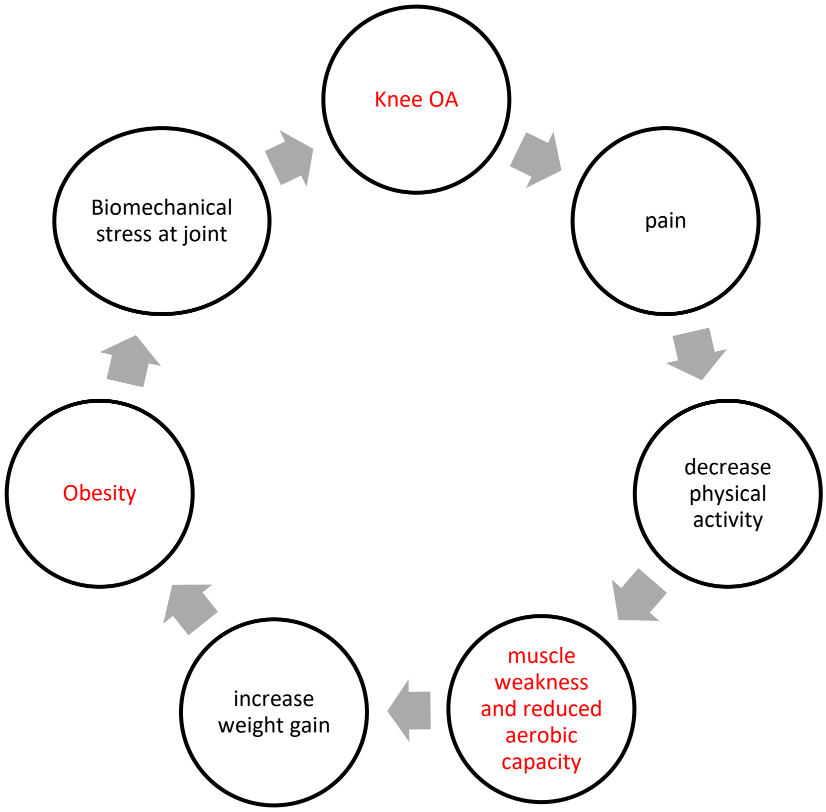

Figure 2 Relationship between PF, PA and knee OA, compiled from (Osteoarthritis action alliance 2019; Felson and Chaisson 1997; Miller et al. 2013; Liow et al. 2017)

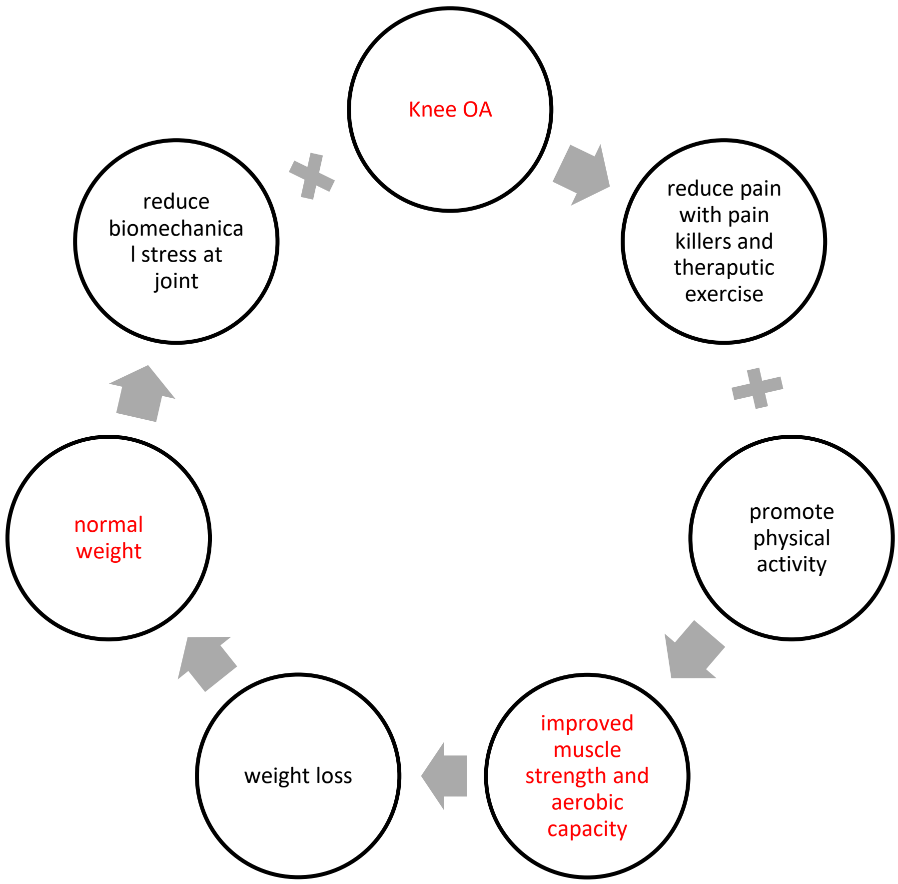

Figure 1 Positive cycle of management of knee OA

2.6. Physical fitness and physical activity in knee OA

As discussed earlier in this chapter, PF and PA are critical indicators of health outcome (Blair et al. 2001a; Ortega et al. 2008). Regular PA is essential to maintain healthy body weight, reduces the risk of metabolic and cardiovascular diseases in addition to the numerous benefits of PA (Pietiläinen et al. 2008; Fang et al. 2017a). Similarly, a good PF components such as; cardiovascular fitness, muscle strength is a significant contributor to better health (Blair et al. 2001a; Hurtig-Wennlöf et al. 2007; Lee et al. 2012). The PF components and PA may also contribute to reducing the complication of knee OA (discussed in 2.4. Therapeutic Exercise section) or even breakdown the inactivity cycle in knee OA as described on page 48.

2.6.1. Physical fitness and knee OA

Only two studies on the PF of individuals with knee OA have measured all the components of health-related PF and balance within the same sample (Table 6) (Cavalcante et al. 2015; Vårbakken et al. 2019a). Cavalcante et al. (2015) carried out a case-control study to evaluate functional fitness as an indication of self-reported quality of life in older with knee OA. Ninety female participants aged over 60 were allocated in two groups: 50 radiographic, symptomatic knee OA individuals and 40 healthy controls. Functional fitness was measured with six tests, which included all the components of PF; Arm Curl Test for upper limb strength, Chair Stand Test for lower limb strength, Timed Up and Go Test for agility and dynamic balance, Sit and Reach Test for assessing flexibility, a test for Static Balance, and Functional Exercise Capacity by 6-minute walk test. The results showed a significant difference between the groups at all the functional fitness tests.

Moreover, the study also evaluated the difference in the time spent in PA, showing that the OA group spent less time than the controls (control= 220 ± 12, OA= 100±10; minutes). However, although this study measured all the physical fitness components in knee OA, it is limited to older females, which may not be generalizable to the knee OA population. In addition, the tests used to measure muscle strength and aerobic capacity has several limitations. For instance, the validity of the chair stand test has been questioned (Whitney et al. 2005), and studies have shown that the test is influenced by balance, sensorimotor, and psychological factors (Lord et al. 2002), which may be interpreted as a functional independence test rather than muscle strength (McCarthy et al. 2004). On the other hand, the 6-minute walk test used for aerobic capacity was not recommended by the American College of Sports Medicine (2017) for individuals at increased risk for musculoskeletal complications, and there is limited evidence on its validity (Dobson et al. 2012). Therefore, a proper assessment of these components would be essential with the higher quality tests or a gold-standards measure.

Another exploratory cross-sectional case-control study was carried out to measure the difference in 27 functional measures in individuals with knee OA compared to healthy controls (Vårbakken et al. 2019a). The study aimed to evaluate biopsychosocial aspects according to the International Classification of Function, Disability, and Health (ICF). Consequently, 28 knee OA individuals and 31 healthy controls were assessed with several tests, including isokinetic concentric knee extension strength, six-minute walk distance test [6MWT] for aerobic capacity, Timed maximum 30-second single-leg stance for static balance and Timed up and go for dynamic balance. Participants also wore an accelerometer to assess their physical activity level, knee osteoarthritis outcome score (KOOS) to assess knee-related problems. Nevertheless, the statistical analysis showed that the OA group was significantly lower than the controls at all the functional measures, with less time spent in physical activity (Table 6). However, the OA group participants were significantly older than the controls (61.7 years in the OA group compared to 55.3 years in the controls), which may have affected the study's outcome as ageing tend to reduce the PF components (Riebe et al. 2009; Milanović et al. 2013). Moreover, though the six-minute walk test for aerobic capacity may indicate the aerobic capacity, it has a limitation in terms of its interpretation that were discussed later in the methods chapter. Lastly, flexibility is considered one of the essential PF components associated with muscle strength, pain and functional activities, which was not measured in the previous study.

Regardless of the limited amount of evidence of affected PF components in knee OA individuals (Table 6), there remains a lack of studies on PF components within the same knee OA sample, especially in the Saudi Arabia population. Therefore, the following discussion of the literature is based on each PF component alone, their assessment procedures, values in knee OA individuals and the evidence for effective therapeutic interventions.

Table 6 physical fitness in knee OA studies

Study	Study type	Population	Outcome measure	Results	Limitations
Cavalcante et al. (2015)	case-control	90 females aged over 60 years old in two groups; 50 radiographic, symptomatic knee OA group and 40 healthy controls group	Time spent in physical activity and Functional fitness was measured with six tests; Upper limb strength with arm curl test Lower limb strength with chair stand test agility and dynamic balance with timed up and go test flexibility with sit and reach test Static Balance with timed-maximum 30 seconds single-leg stance Functional Exercise Capacity with a six-minute walk test	The OA group spent less time compared to the controls (control= 220 ± 12, OA= 100±10; minutes). The OA group was significantly lower at all the functional fitness tests. Upper limb strength (OA mean= 18, SD= ± 4; control mean= 22, SD= ± 6) Lower limb strength with chair stand test (OA mean= 13, SD= ± 5 rep; control mean= 22, SD= ± 5 rep) Agility and dynamic balance (OA mean= 29, SD= ± 4 sec; control mean= 18, SD= ± 6 sec) Flexibility (OA mean= 12, SD= ± 5 cm; control mean= 23, SD= ± 4 cm) Static Balance (OA mean= 11, SD= ± 3 sec; control mean= 18, SD= ± 4 sec)	The study may be limited to only females aged over 60 years, which may not be generalizable to the knee OA population. In addition, the tests used to measure muscle strength has limited evidence with questionable validity. Similarly, the functional exercise capacity has limited evidence on its validity for aerobic capacity, but rather it is a measure of function and walking endurance. Finally, all the tests were carried out on the same day, and the authors did

				Functional Exercise Capacity (OA mean= 297, SD= ± 143 m; control mean= 635, SD= ± 142 m)	not describe the tests' sequence. Hence, the results could be influenced by inappropriate sequence, and they could be affected by fatigues.
Vårbakken et al. (2019a)	exploratory cross-sectional case-control	28 knee OA individuals and 31 healthy controls	ICF evaluation of functional measures such as; Strength with an isokinetic dynamometer Aerobic endurance with a 6-minute walk test Static balance with timed-maximum 30 seconds single-leg stance Dynamic balance and mobility with Timed up and Go test Physical activity level with an accelerometer	The OA group was significantly lower than the controls at all the functional measures, with less time spent in physical activity. Knee extension strength (OA mean= 1.16, SD= ±0.48 Nm/kg; Control mean= 1.46, SD= ±0.38 Nm/kg; P= 0.010) Aerobic endurance (OA mean= 642.5, SD= ± 94.6 m; Control mean= 717.4, SD= ± 75.4 m; P= 0.001) Static balance (OA mean= 10.8, SD= ± 3.1 sec; Control mean= 7.8, SD= ± 1.1 sec; 3.6E-5)	The study may be limited to knee OA individuals with BMI classes lower than obesity two and three. The participants in the OA group were significantly older than the controls. In addition, the aerobic capacity 6MWT has limited evidence on its validity for aerobic capacity, but rather it is a measure of function and walking endurance. Moreover,

				Dynamic balance (OA mean= 6.6, SD= ± 1.2 sec; Control mean= 5.7, SD= ± 0.9 sec; P= 0.001) Physical activity (OA mean= 286, SD= ± 169.1 min/week; Control mean= 382.5, SD= ±0 134.5 min/week; P= 0.018)	Flexibility, a component of PF, was not measured

2.6.1.1. Body composition

Body composition is defined as the percentage of fat and fat-free body mass; the higher the proportion of fat-free mass over fat mass, the healthier the body (American College of Sports Medicine 2017). Body fat provides energy, protection to some organ and regulates hormones. It can be found in muscle, under the skin and around organs (Howley and Thompson 2017). Examples of fat-free mass are bone, muscle, water and tissue, all with their essential function. It is essential to recognize the health-related changes in body composition associated with ageing, such as sarcopenia, which is defined as loss of muscle mass, strength, and physical function (Papalia et al. 2014). Sarcopenia is associated with reduced ability to perform daily activities and an increase in the risk of musculoskeletal injuries (Pickering and Chapurlat 2020). It is also associated with falls, fractures, morbidity, mortality, poor quality of life, depression and hospitalisation (Batsis and Villareal 2020). In individuals with musculoskeletal diseases, accelerated development of sarcopenia has been reported (Papalia et al. 2014), especially in adults aged 65 and older. Therefore, the measurement of body composition is fundamental for research studies as well as in clinical practice. It aims to provide health care provider with data that can play an essential role in the treatment plan (Abbate et al. 2006).

2.6.1.1.1. Assessment

Measurement of body composition can be carried out in the laboratory and the field, but methods vary in complexity, accuracy and cost (Wells and Fewtrell 2006). One example of a body composition measurement tool is the skinfold measurement; it is one of the most commonly used quick and straightforward techniques (Wells and Fewtrell 2006). It relies on the principle that the amount of subcutaneous fat correlates to the total body fat. However, skinfold measurement is dependent on the technician expertise and patient fat mass; hence it significantly contributes to measurement errors (American College of Sports Medicine 2017). Another method to measure body composition is Body Mass Index (BMI); it is the simplest method to calculate body composition. It assesses the relative weight to height by dividing the weight in kilogram by height in meters square. The WHO has categorised BMI results in adults as; normal if BMI between 18.50 - 24.99 kg/m^2, overweight between 25.0-29.9 kg/m^2 and obese if BMI ≥ 30 kg/m^2 (Nishida et al. 2004).

These categories are well recognised and accepted by the major international health organisations such as ACSM, American College of Cardiology (ACC), Centres for Disease Control and Prevention (CDCP), the American Heart Association (AHA) and The Obesity Society (TOS) (American College of Sports Medicine 2017).

2.6.1.1.2. Body composition and knee OA

Obesity causes systemic inflammatory, metabolic effects, and local biomechanical effects on OA, leading to an increase in the risk of knee OA almost three times, compared to a healthy weight (Prieto-Alhambra et al. 2014). **Biomechanically**, an increase in joint loading leads to a deleterious effect and stress on the articular cartilage beyond its capabilities, causing degenerative knee OA changes (Teichtahl et al. 2008; Teichtahl et al. 2015). High BMI (BMI ≥ 25) has been correlated with knee OA, in which there is a linear relationship between BMI and joint space narrowing found in knee OA individuals (i.e. the more BMI, the less joint space) (Çimen et al. 2004). In contrast, a decrease in BMI was associated with a 50% decrease in the risk of developing knee OA (Felson et al. 1992). On the other hand, **systemic effects** such as adiposity-linked glucose, adipocytokines and lipid abnormalities, and chronic inflammation, were found to play a role in the pathogenesis of osteoarthritis (Bijlsma et al. 2011b).

Studies have used body composition as a part of the demographic characteristic of the studied sample, and it is rare to find studies that relied only on the BMI as the aimed outcome measure. Moreover, body composition has been investigated in retrospective and prospective studies as one of the risk factors for developing knee OA. Hence, it is challenging to find studies that evaluated BMI of knee OA compared to healthy controls without referring back to the disease's risk factors or other outcome measures. Nevertheless, evidence shows that osteoarthritis individuals have a higher body fat composition than non-arthritic individuals (Onigbinde 2014), while a positive relationship exists between the incidence of knee OA and obesity (Toivanen et al. 2010).

The lifetime risk for developing knee OA was associated with measurement of body composition, in which a BMI of < 25 has a risk of 30% and increases with higher BMI as it reaches up to 61% in people with BMI of > 30 (Murphy et al. 2008). While studies have found that BMI to be a predictor of knee pain, independent of radiographic features (Anderson and Felson 1988; Teichtahl et al. 2008), several other studies found that obesity was associated with radiographically diagnosed OA (Teichtahl et al. 2008; Gunardi et al. 2013). According to Adegoke et al. (2017), BMI is a significant determinant of pain and performance in individuals with knee OA, and that is more evident in individuals with more severe radiographic changes. In agreement with the previous studies, data from several cross-sectional and longitudinal studies suggest that overweight and obesity was correlated with knee pain and OA and proposed to be the main modifiable risk factor (Anderson and Felson 1988; Toivanen et al. 2010; Teichtahl et al. 2015).

The following section reviews the current evidence from the literature search to elaborate on overweight and obesity as a risk factor for knee OA (Table 7). For instance, Silverwood et al. (2015) carried out a systematic review and meta-analysis of 46 cohort studies to determine the risk factors of knee OA. Two researchers independently reviewed the identified abstracts, and a third researcher was involved if a consensus had not been reached. The meta-analyses were conducted to gain a pooled estimate and 95% confidence intervals (CI). The included studies' outcome was the onset of knee pain and OA, either symptomatically or radiographically. The results showed that in 23 studies, being overweight or obese were the leading risk factors for knee OA, with 24.6% of new-onset knee pain was related to being overweight or obese. The authors concluded that body composition needs to be a primary target for preventing knee pain and OA development. Nevertheless, the authors did not discuss the quality of the included studies, which may affect their findings' quality.

Singer et al. (2018) evaluated BMI's ability to predict knee and hip OA incidence in a case-control study. The study included 29 individuals in the knee OA group, while 40 healthy participants were allocated in a control group. Binary logistic regressions were used to determine OA's predictors adjusted for age and sex, in addition to odds ratios (OR) with their 95% confidence intervals (CI) and p values. The findings show that the mean BMI of the knee OA group was significantly higher than in the control group. Moreover, there were statistically significant results in the regression model compared to the control group indicating that BMI is a significant predictor of knee pain and OA. However, the authors acknowledged a potential selection bias in the control group as more health-conscious people volunteered in that group.

Similarly, a case-control study was carried out to explore the ability of knee circumference, body mass index, and range of motion in predicting knee OA in male individuals (Alahmari et al. 2017). Sixty-six individuals with symptomatic knee OA and 60 matched healthy individuals have participated in the study. Both groups completed the Knee Osteoarthritis Outcome Survey-Activities of Daily Living Scale (KOOS-ADL), while healthy participants were exempted from filling out the questionnaire's symptoms section. In addition, the knee OA group completed a numerical rating scale (NRS) to measure the pain based on the patient’s present, best, and worst pain levels over the previous 24 hours. The results show that BMI was significantly higher in the OA group compared to the control group. Moreover, BMI was significantly correlated to pain and KOS-ADL for the OA group, but it was not correlated to the KOS- ADL for the control group. However, although the study showed that knee OA individuals are significantly overweight/obese, it may be limited by the small sample size and inadequate description of the participants' recruitment procedure.

Table 7 summary of body composition studies

Author	Study type	Population	Outcome measure	Results	Limitations
Silverwood et al. (2015)	systematic review and meta-analysis	46 cohort studies	Knee pain and OA	new onset of knee pain: 5.1% due to previous knee injury 24.6% related to being overweight or obese. The main risk factors are: overweight (pooled OR 1.98, 95% confidence intervals (CI) 1.57-2.20) obesity (pooled OR 2.66 95% CI 2.15-3.28) female gender (pooled OR 1.68, 95% CI 1.37-2.07) previous knee injury (pooled OR 2.83, 95% CI 1.91-4.19)	the authors did not discuss the quality of included studies
Singer et al. (2018)	case-control	29 individuals in the OA group, 40 healthy participants	BMI prediction of the incidence of knee OA	means BMI of the knee OA group was significantly higher than in the control	potential selection bias in the control group.

				group (OA mean= 29.0, SD 4.5; Control mean= 26.1, SD 4.0). statistically significant results in the regression model compared to the control group (OR= 1.2; CI= 1.1–1.4; p= 0.01)	
Alahmari et al. (2017)	case-control	66 OA, 60 healthy controls	BMI	BMI was significantly higher in the OA group compared to the control group (OA mean= 29.92, SD ± 5.59 kg/m^2; control mean= 24.43, SD ± 3.28 kg/m^2; p= 0.02) BMI was significantly correlated to pain (Correlation coefficients= 0.300) and KOS-ADL (Correlation coefficients= 0.680) for the OA group, but it was not correlated to the KOS-ADL for the control group	small sample size inadequate description of the recruitment procedure of the participants

Referring back to the inactivity cycle of knee OA, Miller et al. (2013) stated that due to obesity, individuals might experience a cycle of low exercise capacity, physical disability and breathlessness that could lead to physical inactivity, loss of function and further weight gain. Thus, it is maintained that OA, along with ageing and lack of physical activity, could lead to sarcopenic obesity (Godziuk et al. 2018) that is characterised by low skeletal muscle mass, strength and physical function, and associated with a physical disability, falls, extended hospital stays, infection and non-infection related complications, and increased mortality (Janssen et al. 2002; Cruz-Jentoft et al. 2019).

Moreover, though surgical interventions are recommended for individuals with severe OA, obese individuals are advised to lose weight before the surgery as evidence show that those who underwent a total knee arthroplasty (TKA) may not lose weight compared to those who did not do the surgery (Kahn et al. 2016). TKA in obese individuals is technically more challenging, takes longer to perform, and surgical complications are higher in individuals with an elevated BMI (Salih and Sutton 2013). According to Vasarhelyi and MacDonald (2012), TKA surgery would fail more quickly in obese individuals because of the increased load on the joint that would increase wear of the implant. Consequently, there is an agreement among CPGs to consider weight loss as one of the core treatments for knee OA that could be achieved by exercise and dietary management (National Institute for Health and Clinical Excellence 2014; Bannuru et al. 2019). This would indicate the high volume of evidence, the impact of obesity on knee OA and the importance of weight-loss interventions.

2.6.1.1.3. Summary

The measurement of body composition is fundamental for research studies, and it is considered a component of health-related physical fitness. BMI is one of the simplest methods to calculate body composition despite its limitations. In knee OA, being overweight or obese may double the risk of knee OA that increases the joint loading causing degenerative changes as well as systemic inflammatory and metabolic effects. A large body of evidence recognises that obesity is a leading risk factor for knee OA, while several studies found that individuals with knee OA may have higher BMI than healthy controls. Consequently, this could lead to knee pain and limitations in the individuals' functional activities and contribute to the cycle of inactivity in knee OA. Hence, the current CPGs have included weight loss interventions such as exercises as a core treatment for knee OA.

2.6.1.2. Aerobic capacity

Aerobic capacity or cardiovascular fitness is defined as the ability to continue or persist in strenuous tasks involving large muscle groups for extended periods (Corbin et al. 2000). It is the most critical component of physical fitness and frequently used to replicate physical fitness (Hamilton et al. 2008). Cardiorespiratory fitness depends on the integrated physiologic and functional state of the respiratory, cardiovascular, and musculoskeletal systems (American College of Sports Medicine 2017). Several components influence aerobic capacity, including; cardiac output, pulmonary diffusing capacity, the capacity of oxygen to carry blood, and skeletal muscle strength (Bassett and Howley 2000).

Learning about the aerobic capacity status would assess the risk of cardiovascular disease and allow for objective exercise prescription (American College of Sports Medicine 2017). Aerobic capacity is determined by measuring the maximal oxygen consumption in the body, which relates to the respiratory and circulatory systems' ability to provide oxygen during physical activity (American College of Sports Medicine 2017). Hill and Lupton (1923) were the first to define maximal oxygen uptake (VO2MAX) during exercise as the point at which oxygen intake reaches a maximum beyond where no increase in effort can raise it further. In other words, exercise causes a linear increase of oxygen uptake with the increase of load work; thus, as the workload continues to increase, the oxygen uptake reaches a plateau or what called the VO2MAX (Schaun 2017). Currently, VO2MAX is considered the gold standard to assess cardiorespiratory fitness (American College of Sports Medicine 2017).

Aerobic capacity is affected by ageing, in which older adults showed a 55% lower aerobic capacity compared to younger adults (Andersson et al. 2011). Aerobic capacity can also be affected by the physical activity level. Studies have shown that untrained individuals have a 10% reduction in aerobic capacity compared to those who maintain physical activity throughout their lifetime (Kasch et al. 1999). However, with ageing, several physiological changes cause a reduction in the aerobic capacity, such as; reduction in stroke volume, heart rate, cardiac output, respiratory performance, muscle strength and bulk (Fleg 1986; Conley et al. 2000; Lalley 2013). Therefore, the physiological changes with the reduction of aerobic capacity can reduce functional activities and may lead to disability and an increase in mortality (Kalapotharakos 2007). The study of maximal oxygen uptake (VO2max) is usually measured by clinical exercise test.

2.6.1.2.1. Assessment

Exercise testing has commonly been used with athletes and individuals as a routine clinical assessment. It aims to educate the healthcare provider about the health/fitness status of the participant and provides data that can help create an individualised exercise prescription to address fitness (American College of Sports Medicine 2017). In addition, it would allow the evaluation of current or follow up treatment and setting future goals. According to Howley and Thompson (2017), there are four indications for clinical exercise testing: (1) diagnostic; (2) functional assessment; (3) assessment of disease severity; and (4) monitoring. Moreover, two types of exercise testing can be used in research and the clinical setting: 1) maximal and 2) submaximal exercise tests.

2.6.1.2.1.1. Maximal exercise test

Maximal exercise testing or maximum oxygen consumption testing has been defined as the maximum rate of oxygen uptake during graded exercise (Shephard 1995) or the plateau of Vo2 with further increase in workload (Smith et al. 2016). It is widely used to assess cardiovascular health, individual performance and to develop exercise prescriptions (Sartor et al. 2013). It is considered the gold standard in cardiovascular fitness measurement (Poole and Jones 2017). However, maximal exercise tests might cause health risks of adverse events in individuals with cardiac, respiratory and musculoskeletal disease (Noonan and Dean 2000); since it requires a maximum effort of participants to tolerate the incremented intensity to reach the maximum stress possible. Moreover, its relationship to everyday activities is weak and limited since the individual performs a series of submaximal, short daily tasks (Sartor et al. 2013). Accordingly, it has been shown to be weakly related to daily physical activity and quality of life (American College of Sports Medicine 2017). The individual's motivation strongly influences the direct measurement of VO2max by maximal exercise test, and it requires the achievement of maximum effort for accurate measurement (Arena et al. 2007). In this scenario, elderly individuals or individuals with cardiac disease are not advised to reach this maximum effort since it may increase the risk of adverse events (Arena et al. 2007). Therefore, maximal exercise tests require specialised training, qualified medical monitoring, emergency equipment, and significant participant motivation (Beekley et al. 2004; Sartor et al. 2013).

Moreover, in individuals with a musculoskeletal disability, it has been argued to affect maximal exercise tests' accuracy, which they often excluded (Philbin et al. 1995b; American College of Sports Medicine 2017). Hence, the choice between maximal and submaximal exercise tests is dependent on the participating population and the available resources.

2.6.1.2.1.2. Submaximal exercise tests

On the other hand, submaximal exercise tests are developed to estimate the Vo2 Max in a safer and less risky method. It aims to determine the heart rate response to submaximal work rate and predict VO2max (Smith et al. 2016). The submaximal test examines the participant aerobic capacity below the workload that induces angina (Noonan and Dean 2000). It is considered a valid and reliable alternative to maximum exercise tests while it needs less strict supervision and lower cost with lower health risk (Sartor et al. 2013). Submaximal exercise tests may be single-stage or multistage, with a continuous or discontinuous workload and a predetermined endpoint. These endpoints are (1) target heart rate, (2) oxygen requirements, (3) number of steps, and (4) workload (American College of Sports Medicine 2017). There are many protocols for submaximal exercise tests, the choice of which protocol depends on several factors stated by Sartor et al. (2013), such as the study population, equipment availability, level of exertion, parameters on which the estimation is based and other factors.

According to ACSM (2017), there are several testing modes, such as field tests, motor-driven treadmills, mechanically braked cycle ergometers and step tests. Among these tests, the two most commonly used are the 6-minute walk field test (6MWT) and the cycle ergometer tests. The advantages of 6MWT are that it is inexpensive, practical for a large sample; however, it was maintained that this type of test might not be appropriate for individuals with cardiovascular or musculoskeletal conditions (Noonan and Dean 2000).

Moreover, the test may achieve maximal effort rather than submaximal in individuals with low aerobic capacity, as it is affected by the subjects' motivation and pace (Andersson et al. 2011). The results from 6MWT are interpreted in meters to reflect the functional performance status rather than predicting VO2max (Kovar et al. 1992), which may not sufficiently represent the aerobic capacity (American College of Sports Medicine 2017). To measure VO2max in this test, a portable metabolic system that measures oxygen uptake during exercise may be used in conjunction with it (American College of Rheumatology 2015). Therefore, due to these limitations, the ACSM (2017) asserted that the gold standard in submaximal exercise testing for individuals with chronic illness undergoing rehabilitation is the symptom-limited incremented cycle ergometer.

Sartor et al. (2013) suggest that the cycle ergometer is ideal for clinical testing since it enables additional medical monitoring while decreasing the learning effect with accurate workload determination. In addition, in subjects with musculoskeletal disabilities, cycle ergometry was more appropriate for reducing the workload on the lower limbs joints (Arena et al. 2007). In (2004), Eng et al. studied the test-retest reliability of cycle ergometer submaximal exercise and concurrent validity with maximal oxygen consumption in individuals with chronic stroke. A convenient sample of 12 community-dwellings with medically stable conditions were voluntarily involved in 4 exercise tests on separate days; a maximal cycle ergometer test, a submaximal 6 minutes' walk, a submaximal treadmill test and a submaximal cycle ergometer test. The authors combined the cycle ergometer tests for the maximal and submaximal, and submaximal VO2 corresponded to 85% of the age-predicted maximum heart rate. The test-retest reliability results of the maximal and submaximal cycle ergometer exercise measures show a very high correlation (ICCs > 0.9), while the submaximal treadmill test was categorised as high (ICC=0.75). Furthermore, the submaximal VO2 measures of the cycle, treadmill, and 6MWT were 81%, 77% and 70%, respectively, of the VO2max values. The results also demonstrate the submaximal cycle ergometer's good concurrent validity against the maximal exercise (Pearson Product Moment Correlations, r= 0.80). A significant limitation of this study was the small sample size and the generalizability of this sample. Submaximal exercise testing may not be as precise as maximal exercise testing, but it can provide a reasonably accurate reflection of an individual's cardiovascular fitness level at a reduced risk (American College of Sports Medicine 2017). Moreover, the cycle ergometer allows a submaximal exercise test to be performed while eliminating balance and mobility barriers to assessment (Francesco et al. 2007). There are two commonly used protocols for submaximal cycle ergometer exercise testing; 1) the Astrand-Rhyming cycle ergometer test and 2) the YMCA test.

2.6.1.2.2. Aerobic capacity and knee OA

Historically, research exploring the aerobic capacity of individuals with knee OA were limited due to the assumption that the musculoskeletal disability could affect the diagnostic value of the exercise testing of VO2MAX (Philbin et al. 1995b). The first research to explore individuals' aerobic capacity with knee OA was a study by Minor et al. (1988), which measured exercise tolerance with disease-related measures in OA individuals. A maximal exercise treadmill test was used to measure the aerobic capacity of 80 participants aged between 21-83 years old with symptomatic knee OA. The mean aerobic capacity results ranged between 17-22 ml/kg/min, which implies that individuals with knee OA were significantly impaired in exercise tolerance compared to norms, while females demonstrated a more significant aerobic impairment than males. Nevertheless, this was the beginning of the aerobic capacity of OA individuals, and this study did not compare the aerobic capacity of knee OA to a control group. Moreover, the accuracy of maximal exercise tests with elderly individuals is questionable since they may not reach their maximum effort and treadmill protocols were believed to stress the joint and leads to pain (Philbin et al. 1995b; American College of Sports Medicine 2017).

Later, the same authors carried out another study to explore the effectiveness of a physical exercise programme on the aerobic capacity of OA individuals (Minor et al. 1989). The study included 80 symptomatic knee OA individuals that were randomly divided into three groups: aerobic walking exercise, aerobic aquatic exercise and range of motion exercise control group. The treatment was applied for 12 weeks, while aerobic exercise groups' heart rate was ranged between 60%-80% of the maximal heart rate. All groups received flexibility, isometric strengthening and range of motion exercises. The outcomes were exercise tolerance by maximal exercise test, flexibility and daily activity level, measured at baseline and after 12 weeks of treatment. At follow up, individuals in the aerobic exercise groups showed a significant improvement in aerobic capacity compared with baseline (2.58 ± 5.9) and an increase of 4 ml/kg/min after one year follow up, while the control group showed no change in the mean aerobic capacity. However, 70% of the control subjects showed an increase in aerobic capacity at the 9-month follow up due to the continued exercise. Hence, it indicates that individuals with knee OA can tolerate the exercise testing, and improvements of aerobic capacity can be achieved with appropriate therapeutic exercise protocols, which could lead to an improvement in the functional activities of daily life. However, the study did not compare these findings with healthy non-arthritic individuals, which could highlight the difference in aerobic capacity between OA and healthy groups.

A study by Philbin et al. (1995a) evaluated aerobic capacity testing's feasibility in individuals with knee OA. They compared data from 61 individuals with severe radiographic OA and 23 controls. Using arm or leg ergometry, the participants performed a maximal symptom-limited cardiopulmonary exercise test. Participants were monitored pre, post and during tests with electrocardiography and blood pressure readings. A high number of participants were able to complete the test without complication, and it demonstrated that individuals with knee OA could safely perform a maximal exercise test; in particular, among 30 individuals were undergoing knee replacement, 57% completed leg tests. The results showed a reduction in aerobic capacity (peak 15.1 ml/kg/min) compared to healthy controls. However, the authors did not provide the control group's aerobic capacity values, which does not allow for comparison between groups, regardless of what they demonstrate in their discussion.

Another study by Philbin et al. (1995b) evaluated cardiovascular fitness in individuals with end-stage OA. The study included 37 participants in two groups, 18 knee OA, and 18 healthy controls, who carried out a maximal, symptom-limited exercise test (arm or leg ergometry) with a metabolic cart to measure gas exchanges. The findings show the knee OA group had a significantly reduced VO2 compared to controls (OA peak VO2 mean= 12.85 ± 3.7, control mean= 17.6 ± 5.2). However, the study was outdated and small in sample size, which could indicate type 2 error as the true difference could be small, variability is large; hence it may not have the statistical power to find difference between groups (Faber and Fonseca 2014). and the literature suggested that the maximal exercise test may not be appropriate for chronic conditions due to estimation errors (Evans et al. 2015).

Several studies in the literature have used 6-minutes' walk test (6MWT) in individuals with knee OA, of which they interpreted their findings as functional performance in meters rather than oxygen consumption (Steffen et al. 2002; Stratford et al. 2006; Gomes-Neto et al. 2016; Baldwin et al. 2017). These studies showed a reduced functional performance in knee OA individuals, which could demonstrate the reduced aerobic capacity. However, the measurement of oxygen consumption should result in actual or predicted VO2max in order to accurately compare the findings with normative values in the literature (Bennell et al. 2011; American College of Sports Medicine 2017). Moreover, the application of 6MWT was argued for individuals with knee OA due to the limited available evidence (Dobson et al. 2012). Also, the American College of Sports Medicine (2017) does not recommend this type of testing for sedentary individuals or individuals at increased risk for cardiovascular and/or musculoskeletal complications.

2.6.1.2.3. Summary

Overall, aerobic capacity is an essential component of physical fitness that can determine the individual's capacity to perform exercises and functional activities. Although they may be considered outdated, the previous studies may indicate that knee OA individuals are affected by low aerobic capacity, which could result in activity limitations that would further lead to muscle weakness and weight gain (Relationship between PF, PA and knee OA). Thus, a therapeutic exercise in the form of aerobic exercises is promoted as a core treatment of knee OA. For instance, the Ottawa panel clinical practice guidelines for the management of knee OA supported that aerobic exercise program with or without muscle strengthening exercises effectively reduces pain, improving physical function and quality of life for individuals with knee OA (Brosseau et al. 2017). Table 8 is a summary of aerobic capacity studies included in this review.

Table 8 summary of aerobic capacity studies

Author	Study type	Population	Outcome measure	Results	Limitations
(Minor et al. 1988)	Case-control	80 symptomatic knee OA	maximal exercise treadmill test	mean aerobic capacity= 17-22 ml/kg/min	did not compare the aerobic capacity of knee OA to a control group
(Minor et al. 1989)	Randomised controlled trial	80 symptomatic knee OA randomised into three groups: aerobic walking aerobic aquatics non- aerobic range of motion (controls)	maximal treadmill test flexibility by sit and reach test	aerobic exercise groups showed a significant improvement in aerobic capacity compared with baseline (2.58 ± 5.9 ml/kg/min) the control group showed no change in the mean aerobic capacity.	No comparison with a healthy control group
(Philbin et al. 1995a)	Case-control	61 individuals with severe radiographic OA and 23 controls	a maximal symptom-limited cardiopulmonary exercise test maximal symptom-limited exercise test, monitored with electrocardiography and blood pressure readings	A high number of participants were able to complete the test without complication reduction in aerobic capacity (peak 15.1 ml/kg/min) compared to healthy controls	No clear description of the results as the authors did not provide the aerobic capacity results of the control group

(Philbin et al. 1995b)	Case-control	37 participants in two groups; 18 knee OA and 18 healthy controls	single, maximal, symptom-limited cardiorespiratory exercise test (arm or leg ergometry) a metabolic cart to measure gas exchanges	reduced VO2 max in knee OA (OA peak VO2 mean= 12.85 ± 3.7 ml/kg/min, control mean= 17.6 ± 5.2 ml/kg/min)	Small sample size Outdated Maximal exercise test may not be appropriate for chronic conditions.

2.6.1.3. *Muscle fitness*

Muscle strength and endurance are health-related fitness components of PF that affect several parts of the body, such as; bone mass, glucose tolerance, musculotendinous integrity, daily living activity, quality of life, and weight management (Williams et al. 2007). The American College of Sports Medicine (2017) has merged the terms; muscle strength and endurance into muscle fitness. Muscle strength defined as “the maximum force or tension level that can be produced by a muscle group” (Heyward 2006). Muscle endurance, on the other hand, has been defined as the ability of a muscle to continue to perform a series of repetitions (>12) before fatigue (American College of Sports Medicine 2017). The advantages of assessing muscle fitness in a clinical setting are numerous; it can be used to identify muscle weaknesses or imbalances that might be targeted for designing individualised exercise training programs (Sapega 1990). Moreover, it can be used as a tool to monitor individuals' progress and be a source of feedback to improve the long term adherence to exercise (American College of Sports Medicine 2017).

2.6.1.3.1. Assessment

Measurement of muscle strength can be achieved through several instruments. However, the gold standards among these instruments are; 1) a closed kinetic chain, Isokinetic dynamometer (ID) and 2) an open kinetic chain, one-repetition maximum (Ferraresi et al. 2013). The one-repetition maximum (1RM) is an individual's ability to lift a maximum load for one repetition when the exercise technique performed correctly (Levinger et al. 2009). This technique is gaining full acceptance since it is simple, does not require laboratory instruments, and is performed at the same pattern during regular training. However, Feiereisen et al. (2010) state that 1RM can be influenced by neuromuscular adaptation to strength exercise, and it has a higher risk of bias compared to other techniques. Moreover, individuals at high risk for CVD, pulmonary, metabolic diseases and health conditions are advised for a more conservative approach to assessing maximal muscle strength (American College of Sports Medicine 2017).

In contrast, an Isokinetic dynamometer provides information about the maximum performance (peak torque) during a constant movement velocity of a specific muscle group at a constant angular velocity (e.g., 60 angles) (Ordway et al. 2006). The ID is “characterised by a fixed speed and a variable resistance that accommodates to the subject's capacity throughout the range of motion" (Taylor and Fletcher 2013). Hence, since ID resistance adapts to the subject's capacity, it is safer and more suitable to use with knee OA individuals than the maximum load during the 1RM test.

2.6.1.3.2. Muscle fitness in knee OA:

Muscle weakness in the lower limb associated with knee OA has been well documented in the literature (Table 9), especially in the hamstrings and quadriceps muscles (Alnahdi et al. 2012). Although there is evidence of muscle weakness in the hip and ankle joints associated with knee OA (Deasy et al. 2016), yet it is believed that quadriceps weakness is strongly associated with radiographic knee OA (Slemenda et al. 1997; Bennell et al. 2013; Aslan et al. 2019). The muscle weakness could result from knee OA or a risk factor for developing OA (Hurley 2003). For example, the literature shows that muscle weakness is a significant risk factor for developing knee OA (Johnson and Hunter 2014; Palazzo et al. 2016). Also, studies show that knee OA leads to the cycle of inactivity, leading to muscle weakness (Felson and Chaisson 1997; Miller et al. 2013; Liow et al. 2017).

The quadriceps muscles were recognised as shock absorbers and stabilisers for the knee, which protect the knee joint surfaces in loading and movement (Segal and Glass 2011). Therefore, weakness in the quadriceps muscles was associated with increasing the risk of damage to joint structures (Englund 2010). A theory behind this weakness is assumed to be a failure of voluntary muscle activation due to fear of pain, joint effusion, joint damage, decreased motivation and fear of further injury (Hurley et al. 1997; Lewek et al. 2004). Another mechanism is that weak quadriceps muscles may fatigue easily, which lead to poor neuromuscular control and sensorimotor function; thus, these impairments in the muscles may lead to loading damage at the articular structures, including menisci, ligaments, cartilage, and bone (Bennell et al. 2003; Hortobágyi et al. 2004). The association between muscle weakness and the clinical features of OA may be confounded by radiographical severity (Glass et al. 2013; Ruhdorfer et al. 2014), the demographic characteristics such as sex (Berger et al. 2012) and BMI (Elbaz et al. 2011).

The main factors that affect the muscle's capability to produce force are cross-sectional muscle area and the activation of the muscle by the nervous system (Alnahdi et al. 2012). In knee OA, research shows a reduction in quadriceps cross-sectional area compared to healthy control (Ikeda et al. 2005). In agreement with the previous study, Petterson et al. (2008) stated that in the affected leg, a 12% reduction in quadriceps cross-sectional area was found, compared to the contralateral leg. On the other hand, studies show that with knee OA, joint dysfunction leads to an inability to activate the muscle fully (Alnahdi et al.

2012). A meta-analysis of 14 studies evaluated the quadriceps volitional activation in subjects with knee OA, comparing the involved, uninvolved and healthy controls limbs. The results show that the activation means 82.2% for the involved limb, 81.7% for the contralateral limb, and 90% for the control limb (Pietrosimone et al. 2011), suggesting that individuals with knee OA would have bilateral quadriceps activation deficits compared to healthy controls.

Recently, an exploratory cross-sectional study evaluated the muscle strength difference between individuals with knee OA and healthy controls (Vårbakken et al. 2019b) (Table 9). Concentric peak strength at 60°/s was measured bilaterally in the hip, knee and ankle joints using the Biodex System 4 Dynamometer. The study included 28 clinically and verified radiologically knee OA individuals, and 31 healthy age-gender matched control. The findings indicated that knee OA groups showed significant muscle weaknesses of the involved joint in hip internal rotation, ankle eversion, external hip rotation and ankle dorsal flexion. More importantly, there was a significant difference in knee extension, which indicated quadriceps weakness in knee OA. However, there was a significant age difference between the groups ($p= 0.0014$), which might explain the difference in the strength, as muscle tend to get weaker with age (Arden et al. 2018a).

In (2016), Park et al. evaluated muscle strength in individuals with knee OA compared to healthy controls. The study included twenty-four individuals with mild-to-moderate radiographic knee OA and 24 healthy controls, assessed by self-reported pain and function and lower-limb maximum isometric force. The findings show that in the OA group, a reduced knee extensor muscle isometric strength compared to healthy controls. In contrast, the knee flexion isometric strength was not significantly different between groups. However, although the study had a small sample size that was not justified by size calculation, it is consistent with other literature regarding muscle weakness in knee OA individuals.

Recently, a study evaluated knee muscle strength and body composition among elderly female with knee OA (Zhang et al. 2020). Twenty-five knee OA individuals aged between 60–70 years and 22 healthy controls participated in an assessment of knee extension and flexion isokinetic strength measurements on an isokinetic dynamometer at angular velocities of 90◦/s. The results demonstrated a significant difference in isokinetic muscle strength, in which the OA group had a lower relative peak extension muscle strength compared to controls and relative peak flexion muscle strength. Moreover, the total body muscle mass percentage of the lower limbs was lower in the OA group than the controls, and the weight of participants in the OA group was significantly higher than that of participants in the control group. Hence, individuals with knee OA were found to have weaker quadriceps and hamstring muscles with lower muscle mass and higher weight results, which could indicate a potential for the development of sarcopenia. However, the study limitations may be ungeneralizable due to the small sample size, the old age group, and females' inclusion only. In addition, the authors did not describe if individuals had unilateral or bilateral knee OA and which limb they used for the analysis, which could significantly affect the outcome of the study.

2.6.1.3.3. Summary

A muscle fitness assessment is an essential component of PF, which helps identify weakness or imbalance in the muscles targeted for treatment. Evidence shows that in individuals with knee OA, there is significant quadriceps muscle weakness. Therefore, studies show that strengthening the quadriceps muscles may increase strength, joint stability, and mobility, which contribute to a better range of motion movements and a better tolerance of pain (Coudeyre et al. 2016a; DeVita et al. 2018; Luc-Harkey et al. 2018). Therefore, strengthening exercises are considered a core treatment in most CPGs (Juhl et al. 2014; Bannuru et al. 2019). The benefits of exercise interventions were significantly evident in the literature and discussed previously in Therapeutic Exercise section.

Table 9 summary of muscle fitness studies

Author	Study type	Population	Outcome measure	Results	Limitations
(Vårbakken et al. 2019b)	exploratory cross-sectional	28 symptomatic knee OA 31 healthy controls	Concentric isokinetic peak strength at 60 angular velocity	Significant difference in hip internal rotation (p= 0.0092), ankle eversion (p= 0.0096), external hip rotation (p= 0.013), ankle dorsal flexion (p= 0.021) and knee extension (OA= 1.15, controls= 1.48, P= 0.012)	significant age difference pain and malalignment were not adjusted.
(Park et al. 2016)	Case-control	24 knee OA 24 healthy	self-reported pain and function lower-limb maximum isometric force	Reduced extensor muscle isometric strength compared to healthy controls (OA= 3.45; SD ± 1.39, control= 4.71; SD ± 0.90, p= 0.001). knee flexion isometric strength not significantly different between groups (OA= 2.38; SD ± 0.91, control= 2.74; SD ± 0.63, p= 0.105	Small sample size
(Zhang et al. 2020)	Case-control	Twenty-five knee OA individuals aged between 60–70 years, and 22 healthy controls	isokinetic flexion and extension at 90 angular velocity body composition	lower relative peak extension muscle strength compared to controls (OA group=1.11, SD ± 0.19; controls= .0.89 SD ± 0.26 Nm/kg; P < 0.05) lower relative peak flexion muscle strength (OA= 0.62 SD ± 0.15; Control= .0.54 SD ± 0.16 Nm/kg; P < 0.05) higher weight in OA group (OA= 62.80 SD ± 9.30; Control= 55.79 SD ± 5.2; P < 0.05)	small sample size old age females only

				lower muscle mass in OA group (OA= 19.96% SD ± 1.51%; Control= 18.47% SD ± 1.49%; P < 0.05)	

2.6.1.4. Balance

Balance is the only skill-related physical fitness component that is commonly affected in the elderly (≥ 45 years old) (Verma et al. 2016), and especially in people with knee OA (Kim et al. 2011). It refers to the body's ability to maintain, achieve or restore the centre of mass within the base of support (Pollock et al. 2000), which is controlled by sensory input, central processing, neuromuscular responses and muscular strength (Kokmen et al. 1978). There are two types of balance; 1) static, which is body posture in the stationary base of support, and 2) dynamic, which is the state of balance during movement or a moving base of support (Huxham et al. 2001). With ageing, knee joint proprioception, dynamic balance and muscle strength decline (Ettinger et al. 1994). Poor balance and stability lead to an increase in the incidence of falls, which causes serious injuries or death (Kramarow et al. 2015). Falls have been identified to be the second-highest cause of death from accidental injury (World Health Organization 2008).

2.6.1.4.1. Assessment

A variety of tools can be used to assess dynamic balance in OA individuals that aim to identify individuals at risk of fall or monitor treatment progress. One of these tools is the Timed Up and Go Test (TUGT), which is a quick and simple functional test that requires the participant to stand and walk 3 meters and walk back to sit down (Chan et al. 2017). The time to complete the test is recorded and compared to healthy subjects (Khalaj et al. 2014), in which a faster time indicates a superior functional performance and a score of ≥13.5 seconds is a cut-point to identify the increased risk of falls (Barry et al. 2014). The test was recommended as a routine screening test for balance in NICE guidelines (NICE 2013), the American Geriatric Society and the British Geriatric Society guidelines (Drootin 2011) and OARSI performance-based tests to assess physical function in people diagnosed with hip or knee osteoarthritis (Dobson et al. 2013). It is also recognised as a measure of agility and mobility (American College of Sports Medicine 2017).

2.6.1.4.2. Balance and risk of falls with knee OA

In knee OA, the impaired muscle strength and proprioception that are an integral element of the balance system are affected (Hinman et al. 2002; Sanchez-Ramirez et al. 2013). Thus, evidence shows that knee OA is one of the most important and common risk factors of falls (Blake et al. 1988; Campbell et al. 1989; Tinetti et al. 1995; Lawson et al. 2015). Approximately 50% of people with knee OA reported falling in the past years (Brand et al. 2005; Williams et al. 2010), and a 60% higher incidence of falls noted in women compared to men with knee OA (Leveille et al. 2002). Balance in OA individuals is affected by various variables such as the severity of degeneration, muscle fitness, knee alignment, proprioceptive acuity and pain (Hatfield et al. 2015). Takacs et al. (2015), in their cross-sectional observational study, found that people with knee OA had impaired dynamic balance due to neural and muscular deficits linked to impairments associated with the disease such as muscle weakness, impaired proprioception, altered postural control, and reduced ROM. Moreover, a study of the physiological risk factors for falls in 35 people with knee osteoarthritis compared to 27 control subjects found that there is an increased risk of falls in knee OA that could be due to deficits in knee extension strength and lower limb proprioception (Levinger et al. 2011).

A cross-sectional study evaluated proprioception, balance and quadriceps strength in female individuals with symptomatic and radiographic knee OA compared to healthy controls (Mohammadi et al. 2008). The study involved 60 participants (OA= 30, control= 30), age, weight, height and body mass index (BMI) matched, while the assessor was blind to the status of the participants (i.e. healthy or OA). Proprioception was measured by an electrogoniometer, whereas a modified Tornvall chair assessed the quadriceps strength. Dynamic balance was assessed with a step test, in which the participants were instructed to stand on one leg and step on 15 cm high step with the other leg, then return to a standing position. The number of times the participant was able to step on the tool and return is recorded and compared between the groups.

Nonetheless, the results show that the balance was significantly lower in the OA group than in the control group. Moreover, in the OA group, the reduced dynamic balance was correlated with increasing weight and reduced quadriceps strength, indicating the importance of strength and weight management in knee OA management. Regarding the limitation of their recruitment strategy, the results are not generalizable as the recruitment was carried out from one local clinic with a majority (85%) graded as severe OA, and no justification was provided for the sample size. Moreover, although the study involved age-matched healthy controls, these participants might have had knee OA signs that they were not screened for, as the authors did not clarify the control group's recruitment. Hence, confounders may have affected the overall results of this study. According to the authors, both groups were BMI matched, which may suggest a selection bias as knee OA has been demonstrated in the literature to be associated with high BMI and obesity, which were exclusion criteria in this study.

Kim et al. (2011) studied balance control of knee OA individuals by using three clinical tests; Tetra-ataxiometric posturography (Tetrax®), TUGT and Berg balance scale. The study involved three age-matched groups; A) Moderate to severe knee OA (39 participants), B) Mild (41 participants), and C) healthy control group (40 participants). The results show that balance was significantly different between groups and was reduced in both knee OA groups compared to controls, while this deficit is more advanced in moderate to a severe group as shown in TUGT. Similarly, in the berg balance scale, although their values were not presented in the study, the authors claim that mild and moderate to severe knee OA patient showed a statistically significant difference compared to the control group. Among the several outcomes in the posturography test (Stability index, Weight distribution index, Fourier index and Synchronization index), the findings also demonstrate a significant difference between OA groups and healthy controls. Nevertheless, the study's strength arises from its larger sample size compared to the previous one and the assessment of the participants in the control group, which limits potential confounders. However, the examiner was not blind to the participants, which may create bias.

Khalaj et al. (2014) assessed balance and risk of fall in individuals with bilateral knee OA. The study involved 60 subjects (50-70 years) divided into three groups; healthy, mild and moderate radiographic knee OA. The dynamic and static balance was assessed using the TUGT and Biodex Stability System, which is a device that assesses balance and neuromuscular control during dynamic stress. Consequently, the comparison between groups shows that bilateral knee osteoarthritis impaired the balance and increased the risk of fall, particularly in people with moderate knee osteoarthritis. Participants in the mild OA group performed the TUGT at an average of 10 seconds, while the moderate OA group resulted in an average of 12 seconds, which is considered at risk of falls. Nevertheless, the study excluded individuals with a history of falls during the last 12 months, which could suggest a selection bias towards individuals with good balance control. Hence, although there was a significant difference between groups, the overall results may be underestimated, and knee OA individuals may take more time to complete the TUGT.

The previous findings of reduced balance in individuals with knee OA were confirmed by Arora and Teli's (2015) cross-sectional study. To illustrate, the study involved three groups; knee OA (10 participants), low back pain (10 participants) and healthy controls (10 participants). The static and dynamic balance were measured by TUGT, Unilateral Stance test and limit of stability test using the Balance Master System. In conclusion, the authors found that in the OA group, participants performed TUGT in an average of 15.1 seconds, maintained as at risk of fall compared to controls. Similarly, the authors also demonstrated the static balance to be reduced in the OA group compared to healthy controls. Nevertheless, these results were questionable as the comparison between the OA group and controls was not presented in the study. Moreover, despite the unjustified small sample size, participants' recruitment location was not described except their inclusion and exclusion criteria, which show that the study aims to measure balance only in elderly individuals who are aged over 60 years old.

Nevertheless, despite the limitations of the previous studies, there is a large body of evidence in the literature agreeing with the previous findings of affected balance in individuals with knee OA. For instance, Moreira and Santos (2017) compared the balance and functional mobility of female individuals with knee OA with and without a fall history. The study involved 64 participants divided into three groups; OA with a history of fall, OA with no history of falls, and a healthy control group. The results show that knee OA participants with a history of fall performed the test at an average of 16.32 ±1.12s, which was slower than those with no history of falls (13.07 ±0.91s). However, both knee OA groups were significantly different from the control group. They conclude that individuals with knee OA, regardless of the previous history of falls, demonstrate a reduced balance and an increased risk of falls. However, the study may be limited to female individuals, and there is a lack of description of the recruitment strategy.

2.6.1.4.3. Summary

Balance is one of the skill-related PF components that was significantly evident in the literature for its deficit in individuals with knee OA. Balance is affected by several systems and processes, through central processing, neuromuscular responses, muscular strength and weight. The affected balance could lead to falls and disabilities associated with it. Therefore, with the evidence that individuals with knee OA may experience increased falls due to muscle weakness and affected proprioception, it is essential to assess and include balance exercises in the management. Table 10 provides a summary of balance studies in knee OA.

Table 10 summary of balance studies

Author	Study type	Population	Outcome measure	Results	Limitations
(Mohammadi et al. 2008)	cross-sectional	60 participants (OA= 30, control= 30)	a step test	the dynamic balance was significantly lower in OA group ($p < 0.001$, number of steps, control= 17, OA= 12) in the OA group, the reduced dynamic balance was correlated with increasing weight ($r = 0.30$, $P < 0.001$) and reduced quadriceps strength ($r = -0.37$, $p = 0.002$)	No clear description of the association of balance and pain, disability. Confounders?
(Kim et al. 2011)	Cross-sectional	Moderate to severe knee OA (39 participants) Mild (41 participants) A healthy control group (40 participants)	three clinical tests; Tetra-ataxiometric posturography (Tetrax®) TUGT Berg balance scale	significantly different between groups, and it is reduced in both knee OA groups compared to controls ($P= 0.000$) the deficit is more advanced in moderate to a severe	the examiner was not blind to the participants, which may lead to a biased result

				group as shown in TUGT (A= 11.0±1.7, B= 8.4±0.9, C= 8.0±1.2)	
(Khalaj et al. 2014)	Case-control	60 subjects (50-70 y), three groups (healthy, mild, moderate)	Dynamic and static balance and risk of fall were assessed using Biodex Stability System TUGT	bilateral knee osteoarthritis impaired the balance and increased the risk of fall, particularly in people with moderate knee osteoarthritis (TUGT= 12s)	Exclusion of history of falls, selection bias
(Arora and Teli 2015)	Cross-sectional	Three groups; knee OA (10 participants), low back pain (10 participants) and healthy controls (10 participants)	TUGT Unilateral Stance test limit of stability test using the Balance Master System	OA group, TUG= average 15.1 seconds	small sample size no description of recruitment location exclusion of younger individuals no comparison between OA and controls, despite their claims
(Moreira and Santos 2017)	Cross-sectional	64 females, into three different groups: 18 subjects with OA and previous history of falls	Womac Berg’s Balance Scale (BBS) the Timed Up and Go test (TUG)	In TUGT, OA participants with a history of fall performed the test at an average of 16.32 ±1.12s,	limited to female individuals, and there is a lack of description of the recruitment strategy.

		24 subjects with OA and no previous history of falls 22 healthy subjects)	stabilization diffusion analysis analysis of the balance the stabiliser of the centre of pressure	slower than those with no history of falls (13.07 ±0.91s) Both knee OA groups were significantly different from the control group (9.59 ±0.45s, p= 0.027). BBS and WOMAC scores were significantly lower for the OA group	

2.6.1.5. Flexibility

Flexibility can be defined as the ability to move the joint around the available range of motion without pain or discomfort (Corbin et al. 2000). Flexibility is an essential component of health-related PF that maintains and facilitates joint movement or, in contrast, causes tissue damage if exceeded beyond the ROM (American College of Sports Medicine 2017). It depends on several variables, including; dispensability of the capsule, warm-up, muscle viscosity, and other tissues' compliance (American College of Sports Medicine 2017). It is part of most health-related fitness battery tests due to the importance of flexibility in preventing musculoskeletal injuries (Langhammer and Stanghelle 2015). The lack of muscle flexibility may lead to the alteration in the joint function and may lead to injuries if full ROM is needed (Kaur et al. 2014). Excellent muscle flexibility could reduce the pain (Joshi and Yadav 2019) and improve joint mobility (Onigbinde 2014). According to Pate et al. (2012), muscle flexibility can improve the joint ROM, which could be achieved by stretching exercises that allow an increase in the muscle-tendon unit's length. Moreover, the American College of Sports Medicine (2017) reported that flexibility could improve postural stability and balance. Also, studies show that stretching would reduce delayed muscle soreness after physical activity (Herbert et al. 2011).

2.6.1.5.1. Assessment

Flexibility is joint-specific, in which total body flexibility cannot be determined by one test. Hence, accurate measurement of specific joint flexibility is achieved through direct and specific joint ROM measurement expressed in degrees (Clarkson and Gilewich. 1989). It can be measured in the laboratory or field tests, while the devices used to measure joint ROM is called goniometers (Pate et al. 2012). The laboratory test is straightforward and direct by applying the goniometer to the joint and measuring the angle or ROM. On the other hand, many field tests for flexibility have been proposed for each joint such as; the shoulder stretch, sit-and-reach, and trunk lift tests (Pate et al. 2012). For knee OA cases, the ‘chair sit and reach’ test is the most commonly used approach to measure the flexibility of the low-back and upper hamstring (American College of Sports Medicine 2017). It is a field test that aims to measure hamstring muscle flexibility (Baltaci et al. 2003). The chair sit and reach test is the modified version of the original sit and reach test that reduces the stress on the leg and back that have been reported in older adults with musculoskeletal problems (Jones et al. 1998).

2.6.1.5.2. Muscle flexibility in knee OA

Onigbinde (2014) assessed hamstring flexibility in symptomatic and radiographic knee OA individuals and compared them with healthy matched controls. Their quasi-experiment measured the flexibility of 44 knee OA subjects and 58 healthy individuals using a modified sit and reach test. The results show that the control group had higher mean flexibility compared to the arthritic group and a significantly better ROM, which suggests that knee OA affects hamstring flexibility. Also, the findings show an association between hamstring flexibility and knee pain that is significantly different between groups (p= 0.001). However, the study did not compare other knee joint muscles' involvement like the quadriceps, which could reveal reduced flexibility compared to the hamstrings. Moreover, in the OA group, it was not described if unilateral or bilateral OA exists and which limb they included in the study; it could be the least involved limb with the non-dominant, which may not provide accurate findings. Finally, there is a significant difference in the age between groups (p= 0.20), as the control group were younger than OA, which may describe the significant difference in the flexibility, as it deteriorates with ageing.

In contrast, Shirazi et al. (2016) compared knee muscles' flexibility in females with knee OA and healthy controls. The study included 23 radiographic knee OA and 23 healthy controls, who underwent flexibility examination with a goniometer for Hamstring, Quadriceps, Adductors, Gastrocnemius and Iliotibial band muscles. In addition, an assessment of joint play was carried out; according to the authors, the normal joint play would indicate that ROM's limitation is due to a lack of flexibility. The flexibility was also tested for correlation with pain measured with VAS. Nevertheless, the findings demonstrate that only hamstring muscles had significant bilateral reduced flexibility. Moreover, hamstring flexibility was significantly correlated with pain intensity in knee OA individuals. Hence, the authors suggest stretching exercises as an essential component of treatment to reduce pain and disability. However, the assessor was not blinded to the participants, which may affect the study's bias and rigour. Also, without justification for the sample size calculation, the study had a small sample size with females only; thus, a larger representative sample may reach different conclusions.

More recently, Joshi and Yadav (2019) measured knee muscles' flexibility in knee OA and healthy individuals. A sample of 60 male and female participants were recruited in two groups; 30 knee OA, 30 healthy control. Measurement of flexibility was carried out by a goniometer for five muscles (Hamstring, Quadriceps, Adductors, Gastrocnemius and Iliotibial band muscles), showing flexibility was significantly reduced in the OA group in all knee muscles. Nevertheless, the study lacked a robust description of the methodology as it is not known if the OA participants had unilateral or bilateral knee OA to accurately compare the affected limb with the other limb or with the other group.

In general, inadequate flexibility in the quadriceps and hamstring muscles is linked to increased risk of injury, limiting the joint range of motion, and increasing pain (Onigbinde 2014). Therefore, joint stiffness in knee OA was associated with decreased stride length attributed to the decreased muscle flexibility (Oatis et al. 2013). A hypothesis for this shortening was proposed by Weng et al. (2009), in which they demonstrate that knee pain and muscle weakness in knee OA would lead to shortening in the connective tissue that is composed of collagen fibres that may become fibrotic, contracted and shortened due to immobilisation and lack of physical activity. In agreement with the previous hypothesis, Shirazi et al. (2016) assumed that due to knee OA pain, individuals avoid flexing their knees for prolonged periods, such as in cross-legged sitting or kneeling, which may influence quadriceps flexibility. Another mechanism was proposed by Arab and Nourbakhsh (2010), as OA's pathogenesis affects the chondrocytes, and in response to joint damage or dysfunction, the quadriceps flexibility is reduced as a consequence of dynamic protection. Nevertheless, studies argue that hamstring muscle has a greater tendency to shorten with knee OA due to patellofemoral compressive force (Weng et al. 2009; Arab and Nourbakhsh 2010; Onigbinde 2014).

2.6.1.5.3. Summary

Individuals with knee OA demonstrate reduced muscle flexibility compared to healthy controls, while the pain, muscle weakness and lack of physical activity are believed to be the factors that caused this muscle shortening and reduced flexibility. Therefore, the CPGs that recommend the use of aerobic and strengthening therapeutic exercise may improve these factors, which could also improve the flexibility of knee OA individuals. Consequently resulting in reduced joint stiffness and improvement in range of motion, functional and physical activities. Table 11 provides a summary of flexibility studies in knee OA.

Table 11 summary of flexibility studies

Author	Study type	Population	Outcome measure	Results	Limitations
(Onigbinde 2014)	Cross-sectional	44 knee OA subjects and 58 healthy individuals	A modified sit and reach test	Control group had higher mean flexibility compared to arthritic group (Control= 25.06 ± 3.26; OA= 22.23± 4.32; P= 0.001). Significantly better ROM (Control= 77.13 ± 9.36; OA= 72.39 ± 11.72; P= 0.03) The association between hamstring flexibility and knee pain is significantly different between groups (P= 0.001).	No description of the affected limb There is a significant difference in the age between groups as the control group were younger than OA
(Shirazi et al. 2016)	Case-control	23 radiographic knee OA and 23 healthy controls	Flexibility examination with a goniometer for Hamstring, Quadriceps, Adductors, Gastrocnemius and Iliotibial band muscles	Only quadriceps muscles had a significant bilateral reduced flexibility (Right, P=0.001; Left, P=0.004).	The assessor was not blinded to the participants, which may affect the bias Small sample size with females only

				Reduced quadriceps flexibility was significantly correlated with pain intensity flexibility (P<0.001).	
(Joshi and Yadav 2019)	Case-control	60 male and female participants were recruited in two groups; 30 knee OA, 30 Healthy control	A goniometer for five muscles (Hamstring, Quadriceps, Adductors, Gastrocnemius and Iliotibial band muscles)	Flexibility was significantly reduced in the OA group in all knee muscles	Lack of robust description of the methodology Unilateral or bilateral knee OA The age range in the study may not be generalisable

2.6.2. Physical activity

2.6.2.1. Physical activity assessment

Physical activity assessment is a complex and multidimensional behaviour that require multiple tools to measure. According to Vanhees et al. (2005), there are three categories of physical activity assessment approaches; **firstly**, the gold standards or criterion methods can be achieved by doubly labelled water, indirect calorimetry, and direct observation. These gold standards are suitable for studies exploring the physical activity level by measuring the amount of energy consumption (Melanson and Freedson 1996; Strath et al. 2013). For example, the indirect calorimetry measures physical activity energy expenditure by heat production or by measuring oxygen consumption and carbon dioxide. However, these gold standards are expensive, time-consuming, require experience in exercise physiology and not suitable for population-based studies (Vanhees et al. 2005; Westerterp 2009; American College of Sports Medicine 2017).

Secondly is the objective measurement of physical activity by accelerometers, pedometers and heart rate monitors. Accelerometers can measure movement in one or multi-dimensions with limitation to complex movements (Westerterp 2009), and the outcome data is a record of body acceleration and deceleration (Chen and Bassett 2005). On the other hand, Pedometers can be used to estimate the energy expenditure associated with walking behaviour, as they estimate the number of steps taken (Chen and Bassett 2005; Strath et al. 2013). The outcome from accelerometers and pedometers can be converted to a meaningful physical activity outcome such as METs or kilocalories (Chen and Bassett 2005). Despite their frequent use in PA research, accelerometers and pedometers validity and accuracy are controversial (Kumahara et al. 2004; Ryan et al. 2006; Corder et al. 2007). For instance, Crouter et al. (2003) evaluated ten pedometers' accuracy in estimating steps, distance, and energy expenditure against the criterion indirect calorimetry. Participants walked on the treadmill at five different speeds while measuring and observing the steps and calculating energy expenditure. The results showed that at slow speeds, the pedometers were underestimating the steps taken, while at higher speeds, both the observed and pedometers calculated steps were equal. However, the distance estimations were less accurate, and the energy expenditure was overestimated.

Another objective measure of PA is the heart rate monitors that indirectly estimate physical activity and energy expenditure, relying on the linear relationship between heart rate and oxygen consumption (Strath et al. 2013). However, previous research has established that heart rate monitors are an unreliable tool for measuring physical activity energy expenditure since it has several confounding factors such as; caffeine, stress, smoking, body position, that affect the linear relationship (Strath et al. 2000; Westerterp 2009). For example, activities requiring upper extremity movement will result in a higher heart rate response than the lower extremity (Strath et al. 2000; Strath et al. 2013).

Thirdly, subjective measures of physical activity by questionnaires. It is the most commonly used tool used for epidemiological studies since they are cheap and easy to apply (Westerterp 2009). It is used to categorise and identify PA domains through self-reported or interviews (American College of Sports Medicine 2017). According to Strath et al. (2013), questionnaires are categorised into three groups; global, recall and quantitative history. Overall, studies suggest that questionnaires are a valid and reliable tool for measuring physical activity, with a strong correlation and agreement for vigorous-intensity PA (Wareham et al. 2003; Johansson and Westerterp 2008; Tomioka et al. 2011). Others suggest low validity and reliability of the questionnaires (Shephard 2003) and less accurate for light- to moderate-intensity activities (Ainsworth et al. 1999; Strath et al. 2004). Compared to the gold standard, double-labelled water, questionnaires showed low correlations as they were underestimating (Maddison et al. 2007; Prince et al. 2008; Rush et al. 2008) or overestimating (Koebnick et al. 2005; Mahabir et al. 2006; Prince et al. 2008) physical activity.

Moreover, questionnaires are subject to individual perception and interpretation of the question and several factors that might influence the answers, such as; age, the complexity of the question, length, personal desire (Westerterp 2009; Strath et al. 2013). Nevertheless, Shephard (2003) maintained that questionnaires are appropriate physical activity assessment tools for epidemiology and group studies. They are ideal in clinical settings and surveillance settings because they are simple to administer, concision and ability to determine PA category as; low, moderate or high (Strath et al. 2013). They can be used to determine the percentage of participants meeting the PA guidelines (American College of Sports Medicine 2017).

Due to the need for internationally comparable data on health-related physical activity, PA questionnaires were created, such as The International Physical Activity Questionnaire-Short Form (IPAQ-SF) (Arvidsson et al. 2005). The IPAQ-SF questionnaire was developed by WHO and the Centre for Disease Control and Prevention (CDC) in the United States as a self-report measure of physical activity. It is the most commonly used instrument for estimating physical activity (American College of Sports Medicine 2017). It consists of 7 questions that aim to reflect the time spent, intensity (Moderate and Vigorous), and activity type in the last seven days. The questionnaire was validated against a criterion method and showed good validity for gross classification of PA level in population in terms of low, moderate and highly active (Philippaerts and Lefevre 1998; Ainsworth et al. 2015). In summary, with the availability of many tools to measure PA that are varied in their validity and reliability, the method's chosen could rely on the resources, time and the study population. Therefore, considering these factors is essential to accurately and reasonably assess the PA of the desired population.

2.6.2.2. Physical activity recommendations and guidelines

To achieve the benefits and avoid the complication of physical inactivity, several organisations have established recommendations for optimum PA level that could reduce the risk of chronic disease, functional limitations, premature mortality and disability (American College of Sports Medicine 2017). For instance, WHO (2010) advises adults aged between 18–64 to do at least 150 min of moderate-intensity aerobic physical activity during the week, or at least 75 min of vigorous-intensity aerobic PA throughout the week, or a combination of both. Moreover, the American College of Sports Medicine (Nelson et al. 2007) has recommended that older adults do moderate-intensity aerobic PA for a minimum of 30 min/ five days per week or vigorous-intensity for a minimum of 20 min/ three days per week. The recommendations suggest that any PA is better than none, and the more active someone is, the better (World Health Organization 2020). These recommendations were supported by several international healthcare organisation such as the National Health Service UK (2019) and the UK’s Chief Medical Officers (Davies et al. 2019), which also recommend older adults undertake PA, which includes balance, aerobic and strengthening exercises.

2.6.2.3. *Osteoarthritis and physical activity*

There is evidence that physical activity may prevent or delay the development of arthritis and the associated disability (Penninx et al. 2001; Dunlop et al. 2005), and PA and exercise are significant components of the rehabilitation process. According to a recent systematic review, there is strong evidence of pain reduction and physical function improvement associated with physical activity (Kraus et al. 2019). Hence, EULAR has reported that individuals with knee OA are advised to do the four physical activity domains as safe and feasible while also following the same recommendations for the general population (Rausch Osthoff et al. 2018). Moreover, the ACSM (2017) and the American Heart Association (Nelson et al. 2007) have recommended that people with musculoskeletal disabilities include physical activity in their daily lifestyle. They suggest performing at least 30 minutes of moderate-intensity exercise five days a week or 20 minutes of vigorous exercise three days a week. The previous recommendations are supported by several organisations and authorities (Dunlop et al. 2011; White et al. 2013; Centres for Disease Control and Prevention 2019).

Nevertheless, adherence to PA in individuals with knee OA is still challenging. For example, in a systematic review and meta-analysis of physical activity studies of individuals with knee OA (Wallis et al. 2013), the results show that among 3266 participants, only 13% were adherent to the PA guidelines. Moreover, a cross-sectional study was carried out to measure PA levels of knee OA individuals using an accelerometer (Dunlop et al. 2011). The study involved 1111 participants, of which only 12.9% of males and 7.7% of females with knee OA have met physical activity guidelines. In addition, 40.1% of males and 56.5% of females were physically inactive. Therefore, osteoarthritic individuals tend to have a sedentary and less active lifestyle (Felson et al. 2007), as they tend to limit their activities due to the pain, which starts the vicious cycle of disuse (Ettinger 1997).

For instance, Thoma et al. (2018) compared accelerometer measurement of PA between symptomatic knee OA and healthy controls in the US. The study included 491 in the OA group, 449 in the control group, while the accelerometer was worn for ≥10 hours/day for ≥four days, and the primary variable was the average min/day spent on PA. The results show that individuals with knee OA were considered to have low activity levels, as they spend approximately 1 to 24 min/day in moderate-vigorous PA. Surprisingly, the same findings were found for the control group, as they show a low level of activity (time-spent in PA= 1-22 min/day). Furthermore, both groups were similar in the BMI category, as they were overweight (OA= BMI of 29.7 kg/m^2; Control= BMI of 27.4 kg/m^2). Nevertheless, the study is unclear, as it did not differentiate between moderate and vigorous PA, which differ in terms of the recommendations and the associated effort. For instance, if the participants are engaging in vigorous activity for 22 min/day, then for a week, it would be 154 min/week, which is the recommended PA, and they cannot be considered low active. A better presentation of the findings would probably allow for comparison with other studies by knowing the percentage of low, moderate and highly active in each group.

In the previously discussed, Vårbakken et al.'s (2019a) study compared 27 functional measures between knee OA and healthy controls. The participants wore an accelerometer for one week to measure the difference in physical activity in four intensities (sedentary, light, moderate and vigorous). The findings suggest that individuals with knee OA were significantly less active compared to healthy controls, in which they spent less time in vigorous-intensity PA (OA mean= 15.3 min/week, Control mean= 63 min/week, $P < 0.001$). However, the results show that the OA group significantly spent more time in moderate-intensity PA (OA mean= 169 min/week, Control mean= 134.5 min/week, $P= 0.018$). Moreover, no significant difference was found in sedentary or light intensity PA. Therefore, the results may indicate that individuals with knee OA may avoid vigorous-intensity PA and more adherent to the moderate ones, which could be due to their awareness and beliefs towards their ability to perform that PA level.

In contrast to the previous studies, which did not find a significant difference in PA between individuals with knee OA and healthy controls, the study of Herbolsheimer et al. (2016) had different results. In particular, data from the European Project on Osteoarthritis were analysed to compare the PA level of symptomatic knee OA and healthy controls in six European countries. The study involved 2141 healthy participants and 410 individuals with knee OA, aged between 65–85 years, who were evaluated with Longitudinal Aging Physical Activity Questionnaire (LAPAQ). The findings demonstrate that people with knee OA were more likely to be obese females with more chronic diseases and a significantly lower PA level than the controls (Total PA of OA= 62.9 minutes/day; control= 81.5 minutes/day; P= 0.015). In addition, the PA levels of knee OA individuals were varied between countries, which was indicated that not only the individual or disease-specific factors are affecting the level of PA, but also the social, environmental, and other contextual factors. Regardless of the significant results, the number of participants is very different between the included studies, and it was not indicated if adjustments were considered to allow a reasonable comparison between the groups.

Similarly, Cavalcante et al. (2015) studied functional capacity and quality of life in females with knee OA. The IPAQ questionnaire was used to estimate physical activity levels in 50 participants with knee OA compared to 40 healthy controls. The results showed that the OA group are considered physically inactive as they spent less time in PA compared to the controls (control: mean= 220 METs min/week ± 12, OA: mean= 100 METs min/week ± 10, P < 0.01). The following Table 12 provides a summary of PA studies included in the review.

Table 12 summary of PA studies

Author	Study type	Population	Outcome measure	Results	Limitations
Thoma et al. (2018)	Case-control	491 symptomatic knee OA and 449 healthy controls in the US	Accelerometer for PA level	Both groups were low active Both groups were overweight	Did not differentiate between moderate and vigorous PA
Herbolsheimer et al. (2016)	Cross-sectional	2141 healthy participants and 410 individuals with knee OA in six European countries	Longitudinal Aging Physical Activity Questionnaire (LAPAQ)	OA group showed lower level of PA compared to controls (Total PA of OA= 62.9 minutes/day; control= 81.5 minutes/day; P= 0.015). PA levels of knee OA individuals were varied between countries	The number of participants in each group is very different, and it was not indicated if adjustments were considered
Vårbakken et al. (2019a)	Exploratory cross-sectional	28 knee OA individuals and 31 healthy controls	An accelerometer in four intensities (sedentary, light, moderate and vigorous) of PA in 1 week	OA group significantly spent less time in vigorous-intensity PA (OA mean= 15.3 min/week, Control mean= 63 min/week, P < 0.001). OA spent more time in moderate-intensity PA (OA mean= 169 min/week, Control mean= 134.5 min/week, P= 0.018).	The participants in the OA group were significantly older than the controls
Cavalcante et al. (2015)	Case-control	90 females aged over 60 years old in two groups; 50	IPAQ-sf for physical activity	The OA group spent less time in PA compared to the controls	It is limited to older females, which may not be

		radiographic, symptomatic knee OA group and 40 healthy controls group		(control= 220 MET min/week ± 12, OA= 100 MET min/week ±10, (P < 0.01).	generalisable to the population of knee OA.

Despite the inconsistency in the previous studies regarding the difference in PA between individuals with knee OA and healthy controls, the evidence of physical inactivity among knee OA participants is well established. According to Escalante et al. (2011), 80% of individuals with knee OA have reported movement limitation, and 25% have been unable to perform simple daily activities. In 1994, Ettinger et al. carried out a study investigating OA's long-term physical function, which shows that 44-71% of OA individuals have difficulty in ambulation. A study by Moseng et al. (2014) indicated that individuals with various musculoskeletal diseases have more reduced physical fitness and do less vigorous exercise when compared to healthy controls. The previous findings confirm the studies by Minor et al. (1988) and Philbin et al. (1995a), in which they state that individuals with OA affecting the weight-bearing joints have less active lifestyles and reduced physical fitness when compared to the asymptomatic population.

The low level of physical activity in knee OA individuals harms their health outcome as it leads to chronic comorbidity, cardiovascular, musculoskeletal disorders and reduces their quality of life (Suri et al. 2012). Although taking more steps daily (walking >6000 steps/day) may reduce the risk for total knee replacement (Master et al. 2018), studies have shown that only a small to moderate proportion of people with knee osteoarthritis meet the physical activity guidelines (Wallis et al. 2013), while others have indicated that a large number of OA individuals are not following the guidelines (Herbolsheimer et al. 2016). Moreover, there is a lack of studies on PA levels of individuals with knee OA in Saudi Arabia. However, this lack of adherence to PA guidelines might be similar to individuals without knee OA. For instance, epidemiological studies found that among 3744 adults, only 16% met physical activity recommendations of at least 10,000 steps daily (Sisson et al. 2012). Among 6329 adults, less than 5% met previous physical activity guidelines of at least 30 min daily of moderate-vigorous PA (Troiano et al. 2008). Although PA guidelines may not be followed by individuals with knee OA or healthy people, we must accept that PA is essential for knee OA patients and the evidence of low physical activity levels among the OA population. This would mean that research would benefit from exploring the barriers and facilitators to PA. Understanding the patient’s attitude and identifying barriers to treatment may assist in designing a treatment plan that is specific to the patient’s needs, which will improve treatment adherence (Mazières et al. 2008). This involves considering factors that determine acceptance, motivation and obstacles to exercise, which were reviewed in the following section.

2.6.2.3.1. Barriers and facilitators to PA in individuals with knee OA

Literature addressing the issue of physical inactivity and the lack of exercise adherence have demonstrated several barriers and facilitators to exercise. Mostly, they are categorised into intrinsic (patient-level) and extrinsic factors (social and environmental) (Dacey et al. 2008). With knee OA individuals, the same factors are usually demonstrated. Identifying these barriers aims to improve PA recommendations' adherence to achieve the potential benefits of exercise (Schutzer and Graves 2004).

Hendry et al. (2006), in their qualitative study, explored the knee OA patient's behaviours towards exercise. The authors interviewed 22 individuals with knees OA aged between 52–86 years who were recruited from primary care settings in north Wales. The framework analysis of the interview transcripts led to the emergence of three themes; physical capacity, beliefs about exercise and motivating factors. First, the physical capacity, which was indicated as the limitation to PA participation caused by knee pain, stiffness and general lack of physical fitness attributed to old age. Second, the participant's beliefs about PA and exercise, which was affected by factors such as personal experience, quality of professional advice and OA aetiology (overuse, obesity, pain). The third is motivational factors, which indicates the presence or lack of motivation; they found that physical activity is influenced by motivators such as exercise for pleasure and social support or lack of motivation such as low priority of exercise, laziness and low income.

The previous findings were supported by Petursdottir et al. (2010), who studied the facilitators and barriers to exercise in OA individuals. In a qualitative phenomenological design, the authors interviewed a purposeful sample of 12 individuals with OA in different locations. Data analysis was based on the Vancouver School of doing Phenomenology', which would create themes, categories, and codes like any other qualitative analysis. However, to obtain a wider picture of the exercise behaviour, each participant's data analysis was carried out separately until saturation was reached. Nevertheless, the authors identified internal and external factors that could be facilitators or barriers to exercise. First, the internal factors; that categorised as individual attributes and personal experience with exercising, such as motivation, personality, self-image, knowledge of the disease, pain, stiffness, perceived benefits of exercise and quality of sleep (Petursdottir et al. 2010).

These factors may or may not influence exercise behaviour; they could strongly or weakly affect the exercise's decision. Second, the external factors; which categorised into social and physical environments. Hence, social factors in terms of family support, healthcare provider encouragement and training partner could poorly or greatly influence OA participants to engage in PA. Finally, environmental factors are associated with weather, transportation, exercise classes, and accessibility (**Error! Reference source not found.**). The authors have also proposed a checklist to be a practical tool in physical therapists' assessment of facilitators and barriers to exercise and interventions (Petursdottir et al. 2010). However, some acknowledged limitations of this study that may influence the findings, such as the selection bias, the research pre-conceived ideas and inclusion of participants who are optimists and physically active.

Recently, another qualitative study of the motivators for and barriers to PA in people with knee OA was carried out (Gay et al. 2018). The study involved 20 semi-structured interviews and two focus groups of symptomatic and radiographic knee OA in France. The findings are consistent with previous studies as they showed that motivators were; physical such as well-being, decreased pain, self-perception, personal such as lifestyle, psychological well-being, social and environmental, while the barriers were psychological fear of pain, lack of motivation and physical knee pain or depression. Nevertheless, there is a lack of studies on the barriers to PA in individuals with knee OA in Saudi Arabia, which could have shown a number of environmental or social barriers that could affect their PA levels. However, it is essential to review the PA levels and barriers in the healthy community in Saudi Araba that could apply to individuals with knee OA.

2.6.2.3.2. Physical activity levels and barriers of a healthy population in Saudi Arabia

The population in Saudi Arabia is considered physically inactive; WHO estimated that 58.5% of the Saudi population are physically inactive (World Health Organization 2016). Moreover, several other research agrees with the previous findings, in which an epidemiological study of 17395 Saudi aged between 30-70 years found that 96.1% of the participants were physically inactive (Al-Nozha et al. 2007).

Al-Eisa and Al-Sobayel (2012) explored the physical activity level among Saudi women as measured by a pedometer and the association between physical activity and health beliefs. One hundred and five participants completed two weeks of pedometer measurements. The findings show a high level of inactivity among Saudi females (average pedometer score over two weeks was 5114 ± 2213 steps) compared the reference to the international recommendation for minimum activity. The results also show an association between physical activity and health beliefs in terms of self-motivation by internal health locus of control compared to external control. Participants were mostly affected by personal characteristics relating to ability, effort, and personal power of control. Similarly, in (2001), Al-Refaee and Al-Hazzaa evaluated the determinants and patterns of physical activity among 1333 adult males living in Riyadh. The physical activity questionnaire showed that over 53% of Saudi males were physically inactive, and another 27.5% were irregularly active. Only 19% of the entire sample were active regularly.

Recently, Al-hazzaa (2018) systematically reviewed the available studies on PA among the Saudi population and examined PA's significant barriers and correlations. After reviewing 65 studies, the results show that the prevalence of physical inactivity ranged between 26% to 85% among males and 43% to 91% among females. The northern, southern and central regions had the highest prevalence of physical inactivity. The prevalence of inactivity among adolescent males was 55.5% and 21.9% among females. Inactivity was associated with unhealthy dietary intake, unhealthy lifestyle habits and high screen time. Moreover, the authors demonstrated barriers to PA among adolescents, which are the lack of time and appropriate place, especially in females, the lack of facility and resources, urbanization, traffic, scorching weather, lack of social support and the absence of female school PA program. In contrast, the most important reason for being physically active was maintaining health or losing weight. However, the authors noted that approximately half of the studies had used un-validated PA instruments, which may affect the overall percentage of physical inactivity. Calculating PA prevalence from different studies using varied PA instruments is complicated and must be undertaken with caution.

More recently, Alqahtani et al. (2021) reviewed the General Authority for Statistics, Household Sports Practice National Survey to investigate the prevenance of physical activity among adults aged ≥15 years across Saudi Arabia. The data shows that the proportion of physically active adults was 17.40% and 82.60% were physically inactive among 26000 families. Hence, despite recent changes and strategies to promote physical activity (Kingdom of Saudi Arabia 2030 Vision 2016), the studies show that physical inactivity prevalence is high.

It is evident that Saudi Arabian population in different regions are physically inactive, and the cultural and environmental barriers to physical activity engagement may describe the reasons behind this issue (Table 13). Health-care providers may have an essential role in promoting PA by providing routine assessment and counselling on increasing PA, improving fitness and reducing sedentary behaviours for their individuals (Lobelo et al. 2018). In addition, healthcare institutions can promote active living and invest and advocate for community health through active transportation, public recreation space, and school health initiatives (Albert et al. 2020). However, healthcare providers' perception and attitude in Saudi Arabia towards the promotion of PA is not known, and the role of delivering PA advice needs to be explored. Whereas studies have shown that it is the responsibility of every healthcare provider who can influence and promote PA in the community and their patients (Oyeyemi et al. 2017; Lobelo et al. 2018). Healthcare providers in some countries may believe that it is the role of physiotherapists to promote PA as they are the healthcare profession who are qualified to prescribe exercises (Fowles et al. 2018; Tuna et al. 2020).

Table 13 summary of studies on PA levels and barriers in Saudi Arabia

Author	Study type	Population	Outcome measure	Results	Limitations
Al-Eisa and Al-Sobayel (2012)	Case-control	105 Saudi females	PA by a pedometer in two weeks, and the association between PA and health beliefs	High level of inactivity among Saudi females (average pedometer score over two weeks was 5114 ± 2213 step) compared the reference to the international recommendation for minimum activity an association between PA and elf-motivation by internal health locus of control compared to external control. Participants were mostly affected by ability, effort, and personal power of control.	
Al-Refaee and Al-Hazzaa (2001)	Case-control	1333 adult males	physical activity questionnaire	53% of Saudi males were physically inactive 27.5% were irregularly active. Only 19% of the entire sample were active regularly	
Al-hazzaa (2018)	Systematic review	65 studies	PA levels and barriers	prevalence of physical inactivity ranged between 26% to 85% among males and 43% to 91% among females. The northern, southern and central regions had the highest prevalence of physical inactivity.	approximately half of the studies have used un-validated PA instruments

				The prevalence of inactivity among adolescent males was 55.5% and 21.9% among females. Inactivity was associated with unhealthy dietary intake, unhealthy lifestyle habits and high screen time. Barriers to PA: lack of time and appropriate place, especially in females, the lack of facility and resources, urbanization, traffic, scorching weather, lack of social support and the absence of female school PA program Facilitators and reason to PA are to maintain health or to lose weight	
Alqahtani et al. (2021)	analysis of national survey data	26000 families across Saudi Arabia	Prevelance of Physical activity	Percentage of physically active adults aged over 15 years was 17.40% and 82.60% were physically inactive. Highest rate of physical activity were in Makkah region with 23.27%, while lowest rate were in Baha region with 3% of physical activity.	

2.6.3. Summary of physical fitness and physical activity

Physical fitness and physical activity are equally important measures for assessing health status, which reduce the risk of developing diseases, obesity, cardiovascular and musculoskeletal complications. Both measures are good predictors of mortality and well-being that aim to improve the quality of life (Myers et al. 2015). Moreover, improvement in PF components could lead to an increase in PA. According to the American College of Sports Medicine (2017), rehabilitation programs should aim to promote health and components of physical fitness. However, in knee OA, each of the PF components was reduced compared to healthy controls, which was evaluated in several studies of each PF component alone. A limited number of studies on the PF of individuals with knee OA have measured all PF components within the same sample. Moreover, studies have found a low level of PA in individuals with knee OA, which could be attributed to the evidence of several barriers to PA such as pain, muscle weakness and low cardiovascular fitness. However, the enormous benefits of PA on various body systems have led to the recommendations for knee OA individuals to increase their PA levels to slow the progress of the disease and prevent further comorbidities (Piercy et al. 2018). Nevertheless, studies have shown that PA level is affected by the number of barriers that could be targeted to promote PA in individuals with knee OA. Furthermore, none of the previous studies evaluated PF components, PA levels, or PA barriers in individuals with knee OA in Saudi Arabia.

2.7. The gap

The literature shows that therapeutic exercise and PA are recognised as a core treatment for knee OA (Bannuru et al. 2019), which could significantly improve pain, function and quality of life in individuals with knee OA that could be associated with improvement in some physical fitness components such as aerobic capacity and muscle strength (Hunter and Bierma-Zeinstra 2019). However, most of the guidelines focus on strengthening and aerobic exercises and lack details on exercise prescription such as frequency, intensity, type, and time. Therefore, it does not address other PF components such as balance, flexibility and body composition, which could also be important components to be included in the treatment plan. Moreover, clinicians may not be able to provide evidence-based therapeutic exercise for knee OA. Consequently, the measurement of PF components together would provide a complete picture of the complication of the disease and functional capacity of OA individuals, which can be considered for treatment (American College of Sports Medicine 2017). However, no studies were found evaluated any PF components with knee OA individuals in Saudi Arabia.

The literature also shows that good PF and PA are required not only for athletes but also for non-athletes to reduce the risk of diseases and maintain a healthy body, lifestyle and improve well-being. Physical fitness level has been proven to be an important marker of health status (Ortega et al. 2008; American College of Sports Medicine 2017) since it gives a clue on the functional status of several body systems (musculoskeletal, cardiovascular, psych-neurological, circulatory and metabolic). Physical fitness could be recognised as an enabling factor for PA, which may stop OA's inactivity cycle and contribute to improvement in health and reduction in mortality associated with knee OA disability. However, there is a lack of studies on the PF of individuals with knee OA that measured all PF components within the same sample. The available studies on PF have demonstrated that PF components were affected in knee OA individuals such as muscle fitness, flexibility, balance, aerobic capacity and high rates of obesity (Kim et al. 2011; Onigbinde 2014; Silverwood et al. 2015; Vårbakken et al. 2019b).

Although aerobic capacity is believed to be the most critical component of PF that determines the individuals' capacity to function without fatigue (Blair et al. 1989; Hamilton et al. 2008; American College of Sports Medicine 2017), it was the most outdated and the least studied component in individuals with knee OA (Minor et al. 1988; Minor et al. 1989; Philbin et al. 1995b; Hurtig-Wennlöf et al. 2007). The limited available evidence on aerobic capacity is believed to be due to maximal exercise test limitations and safety. However, the recent evidence showed that there are alternative options such as a sub-maximal exercise test, which has been developed for older adults and disabilities, and it is proven to be safe and feasible. Moreover, the clinical practice guidelines, physiotherapists, as well as patient awareness may have increased since these studies were published (Osteoarthritis Research Society International 2019).

Physical activity, in turn, is a significant health marker, in which it gives the researcher a view on the metabolic consumption that allows the health care provider to create a recommendation on the specific activity level the patient should seek (Corbin et al. 2000). In addition, learning about the activity level would provide an insight into the impact of knee OA on the patient lifestyle and potential consequences (Myers et al. 2004). Individuals with knee OA were considered physically inactive (Felson et al. 2007; Kraus et al. 2019), which may affect their quality of life and an increase in the associated comorbidities through the cycle of inactivity (Felson and Chaisson 1997; Miller et al. 2013; Liow et al. 2017). Despite the evidence of several barriers to PA (Hendry et al. 2006; Petursdottir et al. 2010), they are encouraged to increase their PA level (Nelson et al. 2007; American College of Sports Medicine 2017). However, knee OA individuals are still inactive, and an understanding of the patient's attitude, awareness, and identifying barriers to PA will help design an intervention specific to the patient's needs to promote adherence to PA guidelines (Mazières et al. 2008). This would provide the researcher with an insight into participant's understanding of the importance of exercise and physical activity. Finally, considering that PA could be influenced by cultural attitude and environment, no studies examined the PA levels on knee OA individuals in Saudi Arabia.

2.8. Research questions and aims

The aim of this study was to evaluate physical fitness and physical activity to support therapeutic exercise prescription for individuals with knee osteoarthritis. However, this study utilised an emergent sequential mixed-method approach and was developed based on the findings of phase 1 and the literature.

2.8.1. Overall research question

What are the physical fitness characteristics and physical activity levels in individuals with knee osteoarthritis and non-arthritic healthy individuals in Saudi Arabia that can guide therapeutic exercise prescription?

2.8.2. Phase One

The first phase of this study aimed to answer the research question:

"Is there a difference in physical fitness and physical activity in people with knee OA and non-arthritic healthy individuals from Saudi Arabia?"

The objectives of the first phase of this study are:

- Measure the difference in physical fitness components, including; muscle fitness, aerobic capacity, balance, flexibility and body composition in individuals with knee OA, and compare the finding with a sample of non-arthritic healthy individuals in Saudi Arabia.
- Measure the difference in physical activity levels in individuals with knee OA compared to a sample of non-arthritic healthy individuals in Saudi Arabia.
- Evaluate patient-rated pain, physical function, and the effect of knee OA on function and activity.
- Survey the participant's barriers and facilitators to physical activity in Saudi Arabia.

2.8.3. Phase Two

The second phase of this study aimed to answer the research question:

"What are the participants' perspectives on the opportunities and barriers to physical activity in Saudi Arabia for individuals with knee osteoarthritis?"

Phase two objectives are:

- Explore the participants' perspectives on the opportunities and barriers to physical activity in Saudi Arabia for individuals with knee osteoarthritis.
- Explore the physiotherapists' barriers and attitude towards clinical practice guidelines in Saudi Arabia.

3. Chapter 3: Methods (phase 1)

The study was a case-control design that aimed to ascertain the measurement of physical fitness components and physical activity levels in a sample of people with knee osteoarthritis and then compare the findings with a sample of non-arthritic healthy individuals. The reason for choosing this type of research design is that the study aims to evaluate potential differences between groups in PF and PA, which can be considered an outcome in knee OA (Mann 2003; Lalor et al. 2013). Compared to other observational studies, the case-control design allows the researcher to select multiple outcomes for controls and individuals with the disease of interest (Rezigalla 2020). A major advantage of a case-control design that it is suitable for long latency chronic diseases such as knee OA (University of Oxford. Center for Evidence-Based Medicine 2020). In this type of research design, an appropriate definition of the cases and controls is essential for selecting participants in both groups (Rezigalla 2020), which described later in this chapter.

3.1. Setting

Data collection took place in Makkah, a major city in Saudi Arabia with an estimated population of around 1578722 people (General Authority for Statistics 2015). The city is well-known for its religious importance as it receives millions of pilgrims every year. It has one University; Umm al-Qura University (UQU), and at least ten hospitals located around the city. However, UQU was the primary location for data collection. Moreover, recruitment was carried out in two hospitals in the city (Al-Noor Specialist Hospital and Hera General Hospital). Both hospitals were located at central locations and had a physical therapy department that receives any type of disease and disability. Ethical approval from Cardiff University School of Healthcare Sciences Research Ethics committee was gained, which had been accepted by the local hospitals and the university as they did not request further ethical approval. However, a request to access the sites was obtained, and an approval letter was gained. Since Saudi Arabia is a conservative country, female privacy was a priority for all sites. Hence, a female therapist accompanied the lead researcher if a female participant was present.

3.2. Recruitment

A request to post the advertisement poster (Appendix A) was obtained at Umm al-Qura University, two shopping malls around the city, two local hospitals, as well as social media advertisement and posts. For instance, the study poster was posted on Twitter, Facebook and WhatsApp. The engagement was high (924 people interacted with the tweet), and approximately 40 individuals were interested and contacted the researcher via telephone or email. The researcher spoke with five physiotherapists working in the two local hospitals in Makkah (Al-Noor Specialist Hospital and Hera General Hospital) about the research and the need for study participants; hence, individuals who were receiving treatment were told about the study by their treating physiotherapist and asked if they are willing to speak to the researcher.

Patient information sheets (Appendix V) and consent forms (Appendix W) were provided via mail or electronically, and they were given the time needed (5 days) to consider if they wanted to participate or to ask further questions. If they were willing to take part, then the physical activity readiness questionnaire (PAR-Q) (American College of Sports Medicine 2017) (Appendix B) and an eligibility screening questionnaire were completed over the phone, covering the study inclusion/ exclusion criteria and the clinical presentation of OA as defined by the American College of Rheumatology guidelines (Altman et al. 1986) (Appendix O). Finally, an appointment was made for data collection.

3.3. Sample

The sample size was calculated based on de Groot et al. (2008) study on physical activity difference between knee OA and non-arthritic healthy individuals in the percentage of movement-related activity. The G-power calculation of an independent t-test was set for a significance level of alpha 0.05, in addition to a statistical power of 80%. The sample size calculation resulted in a sample size of 23 subjects in each group, which was set as the minimum recruitment target in case some participants could not do all the testing procedures. Therefore, twenty-nine participants with knee OA were recruited for the study; Al-Noor Hospital= 8 participants (2 from social media and posters, 6 from a referral clinician), Hera Hospital= 5 participants from a referral clinician, UQU= 4 participants, social media and posters= 12 participants. Twenty-five healthy participants were recruited for the non-arthritic healthy group from social media and posters (UQU= 10 participants, social media= 15 participants).

3.3.1. OA group inclusion criteria

Individuals with symptomatic radiographic OA were included in this study. Physician diagnosis of knee OA with medical report, which was brought to the researcher to confirm the diagnosis. Nevertheless, the clinical diagnosis of knee OA was made according to the American College of Rheumatology and European League Against Rheumatism guidelines (Altman et al. 1990; Zhang et al. 2010), which include at least three of the following signs and symptoms that are associated with knee OA: 45 years or older, stiffness lasting less than 30 minutes in the morning, crepitus, bony tenderness, bony enlargement, no palpable warmth.

In addition, individuals must be able to ambulate independently without walking aid with no potential risk identified with PAR-Q (answered NO to any question other than joint pain). For example, the questionnaire includes a question if the subjects complain from loss of balance and consciousness or heart conditions. If answered Yes, then they are advised to speak with their physicians before participating in the study (American College of Sports Medicine 2017). If answered No, then they can proceed in the study (see Pre-exercise test screening section). Moreover, individuals must be able to read and write in the local Arabic language, understand the nature and process of the research, and complete the required questionnaires. Finally, individuals must be able to give written informed consent.

3.3.2. OA group exclusion criteria

Individuals with any severe medical conditions that are contraindicated from exercise testing, such as unstable angina, uncontrolled symptomatic heart failure, acute systemic infection, uncontrolled metabolic disease (American College of Sports Medicine 2017). Moreover, individuals with knee pain due to other medical conditions that can be confirmed with a physician’s report and not attributed to knee OA, e.g. injuries, Iliotibial band syndrome, Rheumatoid arthritis. Individuals are excluded if potential risk identified with PAR-Q (answered YES to any question other than joint pain). Finally, individuals who are unable to read or write and not able to provide written informed consent were excluded from the study.

3.3.3. Non-arthritic healthy comparator group inclusion criteria

The inclusion criteria for the non-arthritic healthy group were individuals aged 45 and older. Individuals with healthy lower limbs with no prior lower limb surgery, based on the researcher screening of the participants to exclude any pain or disabilities (Obling et al. 2015; Vårbakken et al. 2019a). Individuals must be able to ambulate independently without walking aid or pain at any body part with no potential risk identified with PAR-Q. Moreover, individuals must be able to read and write in the local Arabic language, understand the nature and process of the research, and complete the required questionnaires. Finally, individuals must be able to give written informed consent.

3.3.4. Non-arthritic healthy comparator group exclusion criteria

Individuals were excluded if there was a significant knee injury in the past year or prior lower limb surgery, which may show functional impairments during the physical fitness tests. Individuals with any severe medical conditions that are contraindicated from exercise testing, such as unstable angina, uncontrolled symptomatic heart failure, acute systemic infection, uncontrolled metabolic disease (American College of Sports Medicine 2017). Moreover, individuals were excluded if potential risk identified with PAR-Q (answered YES to any question other than joint pain). Finally, individuals who are unable to read or write and not able to provide written informed consent were excluded from the study.

3.3.5. Pilot study

Before data collection, the researcher was familiarised with the data collection tests and equipment by carrying out a pilot study. One healthy individual participated in an informal testing session at the School of Healthcare Sciences Research Laboratory, Cardiff University. Data collection was carried out for the primary outcomes needed for this study, which started with balance and flexibility tests followed by aerobic capacity and muscle strength testing. The results of this pilot study led to changes in the sequence of the tests, as the participant reported fatigue during the aerobic capacity test, which could be due to placing this test at the end of the session. Therefore, to avoid this fatigue and the need for an accurate measure of aerobic capacity and muscle strength, these components were tested first, followed by balance and flexibility tests. Moreover, the pilot study also led to changes and correction in the reports of each test. Later, in Saudi Arabia, a pilot study was carried out with one healthy individual at the Physical Therapy Department, Umm Al-Qura University. The researcher was also familiarised with the equipment and tested their functionality before commencing the participants' data collection. No changes were needed following the last pilot study.

3.4. Procedures for main data collection

Data collection was undertaken in the physical therapy department, Umm Al-Qura University. All subjects were tested in a single session by the researcher, and the testing room was closed for privacy. The testing session lasted approximately between 45 minutes to 60 minutes. Participants were instructed to refrain from eating two hours before testing (American College of Sports Medicine 2017) and to wear comfortable clothes that do not limit the movement during the test, such as sports clothes, considering that the formal uniform in Saudi Arabia is the thobe, which may not be appropriate for exercise testing. On the day of data collection, the researcher discussed the information sheet and clarified any concerns raised. Afterwards, the consent forms were signed, and approval to start data collection was obtained.

3.4.1. Pre-exercise test screening

After completing and signing the consent form, the researcher discussed any concerns with participants regarding the tests. Afterwards, an additional assessment of the participants' eligibility was carried out, starting with the knee OA participants signs and symptoms according to American College of Rheumatology and European League Against Rheumatism guidelines (Altman et al. 1990; Zhang et al. 2010) in order to confirm the diagnosis of knee OA with the clinical presentation (Appendix O). in addition, PAR-Q was completed to confirm the readiness for exercise testing (Appendix B), if they answered YES to any of the questions excluding the joint question, they were advised to seek advice from their physician before taking part in the study. If the participants were eligible, then their height and weight were recorded with a digital weighing scale (Detecto, A Division of

Cardinal Scale Manufacturing Co, model 338). The participants were asked to remove any items in their pockets and remove their shoes, then stand on the weighing scale whilst looking straight ahead. The researcher lowered the height rod until it gently rested on the top of the participants' head. Then, the digital screen presented the participant's weight, and the researcher recorded the measurement of the height.

Next, four questionnaires were given to the participants; Knee Osteoarthritis Outcome Score (KOOS) (Roos and Lohmander 2003), International Physical Activity Questionnaire-Short form (IPAQ-sf) (2005) and Barriers, Facilitators to PA survey and the Numeric Pain Rating Scale (NPRS) (Nahler and Nahler 2009; Hawker et al. 2011) to determine baseline pain, function, health status, activity levels (detailed description of the questionnaires were be presented later in this chapter). All questionnaires were in Arabic language. The researcher ensured that the participants understood each questionnaire and they were able to ask questions.

Regarding equipment calibration, only the isokinetic dynamometer needed to be calibrated once a month according to manufacture recommendations since it comes factory calibrated (Biodex Medical Systems Inc. 2017). Before the testing session, subjects were given time (3 to 5 minutes) to become familiarised with the testing equipment. Throughout this study, the data collection sequence according to the American College of Sports Medicine (2017) recommendations and the pilot study results as follow in Figure 3.

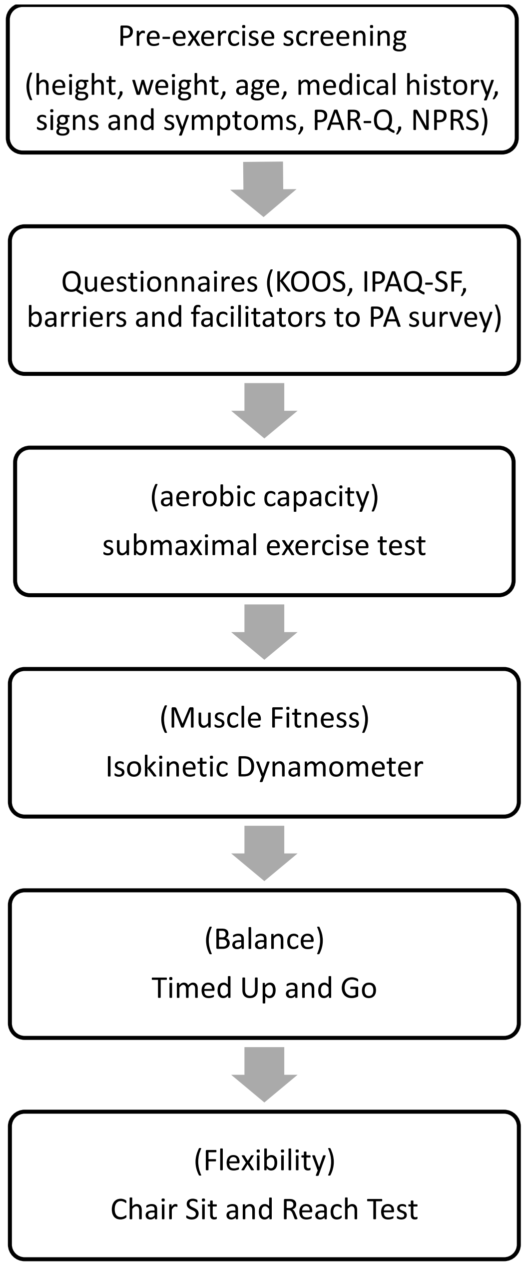

Figure 3 flowchart of the sequence of data collection

3.4.2. Outcome variables

Data collection included aerobic capacity, muscle fitness, balance, flexibility and body composition, in line with the American College of Sports Medicine (2017) recommendations for comprehensive fitness measurement in knee OA individuals. Moreover, physical activity is another essential health behaviour that contributes to PF status or an outcome of good PF, which was measured with IPAQ-SF. The Knee Osteoarthritis Outcome Score questionnaire (KOOS) was also administered to determine knee OA individual's self-rated assessment about their knee health and problems. Similarly, other questionnaires were used to explore the barriers and facilitators to PA and baseline pain (NPRS). In line with the ICF framework's views, these outcome variables include assessment of body function, activity and participation dimensions, and environmental and personal factors (World Health Organization 2001). Table 14 summarises the outcome measures and variables used in this study with their test/questionnaire.

Table 14 outcome variables summary

Outcome variable	Test/ Questionnaire	ICF dimension
Aerobic capacity	Sub-maximal exercise test with Modified Astrand-Rhyming Protocol	Body function and activity
Muscle fitness	Isokinetic dynamometer	Body function
Balance	Timed up and go test	Body function and activity
Flexibility	Chair sit and reach test	Body function
Body composition	BMI	Body function
Physical activity level	IPAQ-SF	Activity and participation
Pain	NPRS	Body function
Knee OA individuals' attitude toward knee health and the effect of OA on function and quality of life	KOOS	Body function, activity and participation
Barriers and facilitators to PA	Barriers and facilitators to PA survey	Environmental and personal factors

3.4.2.1. Aerobic capacity

A sub-maximal exercise test was used to measure aerobic capacity; this followed the Modified Astrand-Rhyming Protocol (Siconolfi et al. 1982). The Astrand-Rhyming submaximal cycle ergometer test was developed over 50 years ago (Astrand and Rhyming 1954). It is one of the most widely used outcome measures for the prediction of VO2max due to its simplicity and the minimal time required (American College of Sports Medicine 2017). However, the Astrand-Rhyming test was developed to predict VO2max in healthy individuals; thus, several studies found the test to overestimate O2 consumption. In (1982), Siconolfi et al. modified the Astrand-Rhyming test to apply to individuals with medical conditions. They aimed to start the test at a low exercise rate that could be completed in a short period of testing, which can be completed by an inactive population. To illustrate, the modified Astrand-Rhyming protocol starts at 25 Watts for males over 35 years and for all females (N.B: male under 35 = 49.0 Watts). For that age group, the exercise rate increase by 25 Watts every two minutes until the target heart rate was achieved. Then, the patient continues pedalling at that rate for two minutes until steady-state heart rate is achieved after the test's termination, a predication of VO2max using the original Astrand-Rhyming nomogram by using the mean of steady-state heart rate and the work rate at the end of the test. Moreover, the age correction regression equation was also modified to adapt to the changes in the protocol. Table 15 shows the difference between the original and modified Astrand-Rhyming protocol.

Table 15 difference between the original and modified Astrand-Rhyming protocol

Original Astrand-Rhyming protocol	**Modified Astrand-Rhyming protocol**
2-3 min warm-up	2-3 min warm-up
Male is different from female	Male and female the same
Not targeted for individuals	Aimed for individuals
Initial work rate 50W	Initial work rate 25W
After 2 min, if HR is < 120 bpm, then increase the work rate	After 2 min, if HR is < 70% of MHR, then increase work rate by 25W
After 2 min, if HR is near 170 bpm, then decrease the work rate	After 2 min, if 70% of MHR is achieved, then continue for an additional 2 min, until steady-state HR is achieved "10 bpm difference in the last 2 min."
After 6 min, if HR is < 70% of MHR, then increase the work rate until 70% MHR is achieved	
if 70% of MHR is achieved, then continue for an additional 2 min, until steady-state HR is achieved "10 bpm difference in the last 2 min."	
Using a nomogram, and corrected by age-factor to calculate VO2max	Using the original nomogram, but corrected with a modified formula to calculate VO2max
Has more evidence and guidance	Limited studies assessed the validity, feasibility and guidance

The modified Astrand-Rhyming protocol procedure used was:

- Participants sat on a stationary bike (Viavito Unisex Satori Exercise Bike). The seat was adjusted so that the participant had 5-10 degrees of flexion at the knee and could complete a full pedalling cycle without restriction. A heart rate monitor on the bike handlebars was used to measure heart rate during the exercise test. In addition, the Borg perceived exertion scale (Borg et al. 1985) was shown to participants to record their exertion at the initial pedalling and on completion of the test.
- Then, the test started with 2 minutes and 45 seconds of rest to allow the resting heart rate to be collected.
- The next step was to begin pedalling at 25 Watts for two minutes. Participants were instructed to maintain cadence between 50-60 rpm. Heart rate was then recorded every two minutes.
- The resistance was then increased through the computerized resistance control by 25 watts every two minutes until 70% age-predicted heart rate was achieved. A sheet was used to record both the participant's heart rate and the resistance level every two minutes (Appendix E).
- When 70% of the age-predicted maximum heart rate was achieved, participant kept pedalling at the same rate with the same resistance until steady-state heart rate was achieved (two consecutive heart rates with less than ten pulses per minute difference). When a steady-state heart rate was achieved, the test was terminated.
- Finally, the participants cooled down for 3 minutes at 5 Watts until the resting heart rate obtained.

The exercise test was terminated early under specific indications such as the participant desire, fatigue, shortness of breath, wheezing, leg cramps and chest pain. All the exercise testing procedures were following the American College of Sports Medicine (2017) guidelines. A formula was used to predict aerobic capacity (Siconolfi et al. 1982):

For Males: $Y = 0.348(X_1) – 0.035(X_2) + 3.011$

For Females: $Y = 0.302(X_1) – 0.019(X_2) + 1.593$

Y is VO2 (l/min), and X_1 is the VO2 (l/min) from the original Astrand-Rhyming nomogram not corrected for age, and X_2 is the age (years). Oxygen consumption can be expressed as an absolute value (l/min) or relative value that is adjusted to body weight (ml/kg/min). Therefore, to convert absolute value to relative value, the following formula was used:

VO2 (l/min) divided by the subject's body weight in kg, then multiply x 1000 = VO2 (ml/kg/min)

3.4.2.1.1. Validity and reliability of submaximal exercise test protocol

The literature shows that this type of testing is safe to be used with OA individuals (Sartor et al. 2013; American College of Sports Medicine 2017). Besides, the protocol has been validated to be used with those individuals as a safe and less risky test environment aimed to estimate VO2max. In particular, Siconolfi et al. (1982) validated their protocol against the original protocol (Astrand and Rhyming 1954) as well as against direct measured VO2max. Sixty-three healthy subjects were recruited in the validity group, aged between 20-70 years old. The validity testing results showed no significant difference between their prediction formula and the direct measurement of VO2max (Direct 2.07 ± 0.74, Astrand-Rhyming prediction 2.19 ± 0.71, Siconolfi prediction 2.09 ± 0.73). Another study by Francesco et al. (2007) examined the validity of this protocol against the direct measurement of VO2max. They conclude that Siconolfis' (1982) protocol is valid, reliable and well-tolerated in predicting VO2max with individuals.

3.4.2.2. *Muscle strength with Isokinetic Dynamometer (ID)*

The participants were given 10 to 20 minutes to rest after the aerobic capacity test to ensure their ability to continue the muscle fitness test. The isokinetic dynamometer is considered one of the gold standards tools in measuring muscle strength and endurance (Ferraresi et al. 2013). It provides information about the maximum performance (peak torque) during a constant movement velocity of a specific muscle group (Ordway et al. 2006). Moreover, the isokinetic dynamometer offers a fixed movement speed with a variable resistance that adapts to the participants capacity through the range of motion (Drouin et al. 2004*).* Isokinetic dynamometer Biodex System 4 (Biodex Medical System, New York, USA) was used to measure concentric and isometric muscle strength. Peak torque was normalised by body weight (PQ/kg) in order to compare the results between participants. The machine was calibrated according to the manufacture manual. A knee attachment was used to measure flexion and extension for each limb. The testing procedure, as recommended by Patsika et al. (2014) and Dvir (2003), was followed.

Since participants had already warmed up during the aerobic capacity test, they did not perform 3 minutes warm-up before this test. Participants were seated with hip joints flexed to 90° so that the knee axis was aligned to the dynamometer axis using the lateral femoral epicondyle as a reference point. The knee, hip and trunk were strapped to stabilize the participants to minimize unwanted movements. A soft ankle cuff was fitted just proximal to the lateral malleolus to control and direct the movement. The range of motion was adjusted from 0° (straight leg) knee extension to maximum flexion the participant can achieve (90° knee flexion). All measurement variables were anatomically adjusted for gravity. The dominant leg was tested first, followed by the nondominant leg for both groups, regardless of which knee was affected. The participant was asked to grasp the handgrips and push or pull as hard as they can without feeling pain. Then, they performed three to five repetitions of concentric flexion and extension at submaximal (70 to 80%) effort and the last one was a maximal effort that aimed to familiarize them with the testing procedures.

Afterwards, the test started with five repetitions of maximal effort at an angular speed of 60°/second followed by 120°/second, separated by 3-minute rest, while providing verbal encouragements to participants in order to achieve their maximum peak torque. Then, participants performed three to five flexion and extension movements with the same equipment but without resistance to cool down. Peak torque was identified as the average value of the five repetitions; hence the results were shown as hamstring peak torque (HPT) and quadriceps peak torque (QPT). However, due to the variation in body composition that could affect the accuracy of the outcome, the results were normalized to relative peak torque calculated by dividing each peak torque to each subject's body weight in kilograms (QPT/BW; HPT/BW) (Biodex Medical Systems Inc. 2017). The dominant limb in the non-arthritic healthy group was compared to the affected or most painful limb in the OA group, according to Vårbakken et al. (2019b) and Cavalcante et al. (2015) protocol.

Concentric peak torques of the quadriceps and hamstrings muscles were measured in both limbs for both groups at an angular velocity of 60 and 120 degrees/second as recommended previously (Gür et al. 2002; Dvir 2003; Alnahdi et al. 2012; Patsika et al. 2014). These values were chosen since the most considerable change in muscular strength tends to occur between 30 degrees/second and 120 degrees/second (Gür et al. 2002; Dvir 2003; Alnahdi et al. 2012; Patsika et al. 2014). Therefore, to detect the difference in muscle strength between knee OA and non-arthritic healthy groups, the angular velocity of 60 and 120 degrees/second were chosen. On the other hand, isometric peak torque was measured by positioning the limb at 30, 40, 50 and 60 degrees according to (Lord et al. 1992; Alnahdi et al. 2012; Vårbakken et al. 2019b), as increasing the angle was found to produce more peak torque and resulting in a better reflection of isometric strength. The participants were instructed to bend their knees to test the hamstring muscle and later to extend the knees to test the quadriceps muscle. Relative isometric strength (Nm/kg) was identified as the average value of the five repetitions.

3.4.2.2.1. Validity and reliability of isokinetic dynamometer

Feiring et al. (2013) assessed the Biodex isokinetic dynamometer's test-retest reliability for a healthy active population for knee extension/flexion utilising the parameters peak torque and work. The data showed the intra-class correlation coefficient (ICC) of knee extension peak torque at 60°/sec to be r = 0.95; at 180°/sec, r = 0.96; at 240°/sec, r = 0.95; and at 300°/sec, r = 0.97. Knee extension work ICC values were at 60°/sec, r = 0.96; at 180°/sec, r = 0.97; at 240°/sec, r = 0.96 and r = 0.95 at 300°/sec. All ICCs were significant at the 0.05

level. Furthermore, Tsiros et al. (2011) assessed the reliability of knee flexor/extensor strength using the Biodex. Peak isometric knee extensor (KE) and peak isokinetic knee flexor (KF) torques were assessed in both limbs in 11 children, 7-10 days apart. The results show that the peak isokinetic KE/KF torque ratios agreed well between tests and had intra-class correlation coefficients (ICCs) of 0.96, which indicates the dynamometer to be reliable means of assessing knee strength. However, the author noticed a learning effect occurred when assessing isometric torque, suggesting the importance of habituation in this measure.

The same results had been discovered by Fagher et al. (2016), in which their study shows a fair to excellent intra-class correlation coefficient for knee extensor and knee flexor peak torques. Moreover, Drouin et al. (2004) evaluated the reliability and validity of position, torque and velocity measurements of the Biodex System 3 isokinetic dynamometer compared to one repetition maximum (1RM). Their study's findings also show that this system is a valid and reliable instrument for the measurement of angular position, isometric torque, and slow to moderately high velocities. Therefore, the Biodex dynamometer was deemed reliable for test-retest measures of peak torque and single repetition work.

3.4.2.3. *Balance and function assessment by Timed Up and Go test*

The Timed Up and Go test (TUG) is a simple, quick and widely used clinical performance-based measure of lower extremity function, mobility and fall risk (Herman et al. 2011). The test procedures used were those of Podsiadlo and Richardson (1991) (**Error! Reference source not found.**):

- The patient sat on a chair with armrests with their back against the back support.
- On the command "go", the patient stood up from the chair without using their hands, walked 3 meters at a comfortable and safe pace, then turned around a cone, walked back to the chair, and sat down.
- Timing began at the instruction "go" and stopped when the patient is seated (time was measured with iPhone X 2017, pre-installed timer application).
- The time between the command to start till the buttocks touch the chair is calculated and reported in seconds.
- The participants had one practice trial that was not included in the score.
- Participants were given three trials, and the average of the three was used as the test score.

3.4.2.3.1. Validity and reliability of Timed Up and Go test

Podsiadlo and Richardson (1991) indicated that this test is a reliable and valid test for quantifying functional mobility and good correlation with the Berg Balance Scale (r = -0.81). Hence, it could be argued that TUGT is a mobility test rather than a balance test. However, Alexandre et al. (2012), in a prospective cohort study, evaluated the accuracy of the TUGT for screening the risk of falls in community-dwelling elderly individuals, which could include knee OA since it is associated with ageing. Based on their sample size calculation, the study included a sample of 63 elderly individuals, which were assessed for the dynamic balance status with TUGT, the occurrence of falls, and ADL to measure the sensitivity and specificity of the TUGT. The participants were divided into two groups of fallers (19) and non-fallers (41). Regarding the sensitivity and specificity, they scored 73.7% and 65.8%, respectively, and the area under the curve was 0.68 (95%CI:0.54-0.83). The author concludes that the test proved to be an accurate measure for screening the risk of falls among elderly individuals. Later, Hofheinz and Mibs (2016) examined the prognostic validity of the TUGT for predicting the risk of falls in the elderly. They studied 120 male and female participants, aged 60 to 87 year over 12 months. At the end of the study, 30.8% of the participants have locomotive falls. The author concludes that the test showed a 95% CI = 0.55, 0.76, which demonstrated the significance of the test in predicting the risk of falls.

In addition, Alghadir et al. (2015b) carried out a reliability study of TUGT with mild and moderate knee OA individuals. Sixty-five subjects aged between 45–70 years participated in the study. Inter-rater reliability was assessed using two researchers at different times on the same day, while Intra-rater reliability was assessed on two consecutive visits within a 2-day interval. The results show that the TUGT was a reliable measure, in which the Intra-rater reliability was 0.97 (95 % confidence interval [CI], 0.95 – 0.98) and inter-rater reliability was 0.96 (95 % confidence interval [CI], 0.94 – 0.97). However, the study sample did not include individuals with severe knee OA, which could increase the variability of performance results; thus, it may reduce the test reliability if test-retest repeated measurements were assessed. Moreover, several other studies evaluated the reliability and validity of the TUGT, which was consistent with the previous study that addresses the test as reliable and valid for use with individuals with knee OA (Kennedy et al. 2005; Yeung et al. 2008; Dobson 2015; Moreira and Santos 2017).

3.4.2.4. Muscle Flexibility with Chair sit and reach test (CSR)

Assessment of joint flexibility was achieved through direct and specific measurement of joint ROM expressed in degrees (Clarkson HM and Gilewich GB. 1989). For this study, hamstring flexibility was measured as it is directly associated with knee OA (Onigbinde 2014). The Chair Sit and Reach flexometer test is the most commonly used approach to measure hamstring flexibility (American College of Sports Medicine 2017). Participants were asked to extend their leg in front of their hip, with the heel on the floor and foot dorsiflexed (at approximately 90°) and bend the other leg so that the sole of the foot was flat on the floor about 6-12 inches (**Error! Reference source not found.**). The extended leg was as straight as possible and hands-on top of each other with palms down; participants were asked to slowly bend forward at the hip joint, keeping the spine as straight as possible and the head in normal alignment with the spine (not tucked). They were instructed to reach down the extended leg in an attempt to touch the toes. The participants were asked to hold a brief static position while the researcher recorded the score using a ruler positioned parallel to the lower leg. If the participant was able to reach the toes or tip of the shoe, that represents "zero". If they were not able to reach the toes, the score recorded as a minus in centimetres, and beyond the toes was recorded as a plus score (Jones et al. 1998). Participants were asked to do the test three times, and the average score was used for analysis (Dobson et al. 2012).

3.4.2.4.1. Validity and reliability of the Chair Sit and Reach test

Jones et al. (1998) examined the Chair Sit and Reach test's validity and reliability and compare it to the original Sit and Reach test and Back-saver Sit and Reach test. The participants were examined on two different days, with 2-5 days between the tests. The results indicate that there is a good intra-class test-retest reliability (R= .92 for men; R= .9 6 for women) of the Chair Sit and Reach test. For validity testing, the author carried out three measures and a criterion test (goniometer measurement of a passive straight leg raises). They found a moderate to a good relationship with the criterion measure (r = .7 6 for men; r = .81 for women). According to Kirschke et al. (2006), the average Chair Sit and Reach test score for males ranges between -3.0 to 3.0, while for females, it ranges between -0.5 to 4.5.

3.4.2.5. Body Composition with BMI

Body Mass Index (BMI) is one of the simplest methods to calculate body composition. It assesses the relative weight to height by dividing the weight in kilogrammes by height in meters square. The Obesity Education Initiative Expert Panel on the Identification Evaluation and Treatment of Overweight and Obesity in Adults (1998) and Bjorntorp et al. (2000) stated that an individual is defined as overweight if BMI between 25.0-29.9, obese if BMI ≥ 30-34.9, obese class 1 ≥ 35-34.9, obese class 2 ≥ 35-40 and over 40 is considered obese class 3. In this study, A Detecto digital height and weight measuring machine weighing scale were used to measure the participants' height and weight in order to calculate the BMI score, which was then categorized to classify and define the participants BMI category. The higher the BMI, the greater is the risk of developing obesity-related health problems (Weir and Jan 2019).

3.4.2.5.1. Validity and reliability of BMI

Regardless of its frequent use, the BMI poorly measures fat percentage (Buss 2014) since it calculates the whole-body weight, but it does not differentiate between muscle, bone, fat or organs. Consequently, a person with high fat-free mass might have a high BMI but may still be considered obese (Wellens 1996; Nuttall 2015). Moreover, compared to other techniques, the BMI was found to lead to an inaccurate estimate of obesity; for example, if an individual's BMI was less than 25 kg/m-2, he might be overweight if it was measured by other techniques (Nuttall 2015). According to Buss (2014), BMI overestimates body fat in muscular persons and can underestimate body fat in persons, such as older adults, who have less muscle mass. In addition, the literature shows that there is a weak correlation between the percent of body fat mass and BMI in males. For example, a meta-analysis of 32 studies compared BMI to six gold standards techniques, which showed a sensitivity of 50% and specificity of 90% that indicated BMI might not be accurate at measuring body fat percentage as it failed to identify half of the people with excess body fat percentage (Okorodudu et al. 2010). Other limitations discussed in the literature were related to the BMI assessment, in which it was indicated that the time of the day could affect the height due to the diurnal variation, the weight could be affected due to the type of clothes worn, or food consumed that day (Buss 2014). Therefore, BMI was repeatedly questioned, and numerous studies suggested the limited use of BMI in epidemiological studies and to learn about the individual's risk of obesity; instead of measuring the actual fat mass and fat percentages at the individuals level (Okorodudu et al. 2010; Buss 2014; Nuttall 2015).

Despite its limitation, BMI has been widely used in research and considered as evidence of obesity and overweight (Wellens 1996; WHO 2015). At present, the BMI is adopted by the majority of health organisations to define the study of the prevalence of obesity; it provided a uniform code for reporting body composition (Nishida et al. 2004; Nuttall 2015). BMI has been recommended for individual use in clinical practice to guide recommendations for weight loss and weight control (Seidell et al. 2001). Additionally, the American College of Cardiology (ACC) and the American Heart Association (AHA) guideline for the management of overweight and obesity in adults reported that BMI has a direct dose-response relationship with the risk of fatal and nonfatal disorders (Jensen et al. 2014).

For example, Khaodhiar et al. (1999) found that an increase in BMI of 1 kg/m^2 in individuals with more than 22 kg/m^2 was associated with a 10% increase in heart diseases. Although the studies indicate the limited correlation between BMI and fat percentage, BMI was found to have a direct relationship with the risk of developing diseases (Tuttle et al. 2016). Hence, BMI was asserted as a tool to assess and classify weight-related health risks and an inexpensive, easy to apply measure for classification of body weight (American College of Sports Medicine 2017). Moreover, BMI is strongly associated with knee OA, and it offers the same data that can be obtained from measurement of fat distribution through skinfold and other techniques (Abbate et al. 2006).

3.4.2.6. Knee Osteoarthritis Outcome Score (KOOS) (Appendix C)

Knee Osteoarthritis Outcome Score (KOOS) developed in the 1990s as a patient-reported outcome measurement instrument that assesses the individuals' attitude about their knee health and problems (Roos and Lohmander 2003). KOOS can be used with individuals aged between 13-79 years and with various knee conditions over short or long intervals. KOOS has five individually scored subscales: Pain (9 questions); Symptoms (7 questions); Function in daily living (17 questions); Function in Sport and Recreation (5 questions) and knee-related Quality of Life (4 questions). The advantage of KOOS over other tools is that KOOS assesses short-term and long-term effects of knee OA and differentiating between daily life and physical recreation activity in two different subscales. Thus, it enhances its validity for individuals with a wide range of current and expected physical activity levels. The validity and reliability of KOOS have been well established in the literature and compared to other scoring tools (Goncalves et al 2009, Ornetti et al 2008, Roos et al 1998, 1998a, 1999, 2003). A valid and reliable Arabic version of the KOOS questionnaire was used since it is the study population's local language (Alfadhel 2006; Alfadhel et al. 2018). The participants completed the questionnaire before completing the physical fitness tests. Furthermore, if a mark was placed outside a box, the closest box was chosen, and if more than 50% of the subscale items were not completed, that subscale was considered invalid. To calculate the scores, a computerised excel sheet was used that presents the scores independently in each subscale from 0 to 100, with 'zero' indicating severe knee problems and '100' indicating no knee problems (available at http://www.koos.nu/index.html).

3.4.2.7. International Physical Activity Questionnaire- Short form (IPAQ-sf) (Appendix D)

To quantify the duration and type of physical activity, the inexpensive and easy to apply International Physical Activity Questionnaire-Short form (IPAQ-sf) was used (the International Physical Activity Questionnaire (IPAQ) 2005). It consists of 7 questions that aim to reflect the time spent, intensity (Moderate and Vigorous), and activity type in the last seven days. Therefore, to explore the participant's physical activity level, the IPAQ-sf-questionnaire was used. This questionnaire's results were entered in an automated Excel sheet that was designed to calculate the overall score and classify the PA level (Cheng 2016). The automated sheet calculates the MET-minutes per week as a continuous measure, resulting in categorizing physical activity levels as low, moderate and high according to the IPAQ Research Committee algorithms (the International Physical Activity Questionnaire (IPAQ) 2005). These physical activity categories and MET minutes per week were used for comparison between the two groups. The validity and reliability of the IPAQ questionnaire were well established in the literature and proven to be a reliable and moderately valid tool to measure PA (Lee et al. 2011; Ács et al. 2020).

3.4.2.8. Barriers and Facilitators to physical activity survey

In this study, a survey was developed based on the Petursdottir et al. (2010) checklist to assess facilitators, barriers, and attitudes to physical activity (**Error! Reference source not found.**). Petursdottir et al.'s (2010) phenomenological study interviewed a number of individuals with OA to determine what they perceive as barriers or facilitators to exercise and aid understanding of an individuals experience of exercise. After they interviewed 16 participants, a checklist was created, which includes factors that range from internal to external factors that influences exercise as barriers or facilitators. This checklist aimed for physical therapists' assessment of barriers and facilitators in individuals with knee OA. According to the author, the more facilitators the patient chose, the more physically active they might be and vice-versa. However, the application and interpretation of the checklist might be inappropriate for this study as it is intended to be completed by clinicians in clinical practice while interviewing the patients, and it is believed to be time-consuming in this study. Hence, a survey was developed based on the internal to external factors found from the Petursdottir et al. (2010) checklist.

3.4.2.8.1. Survey development

For each factor, a question was made to change the style from a checklist into a questionnaire. For example, the personality factor in the checklist has two answers, positive or negative. While in the questionnaire, the personality factor was explored by the question: (How does your personality affect your decision to exercise?). The responses for this question were three choices (negatively, neutral or positively). For other questions, Petursdottir et al. (2010) recommended using different style responses such as; Doesn’t affect, neutral or affect; or not enough, neutral or enough. In the design of the questionnaire, the style of the response was developed to match those recommended by Petursdottir et al. (2010). See Table 16. Nevertheless, 22 questions were made that compile with Petursdottir et al. (2010) checklist. In addition, the researcher added two questions to assess the participants' awareness of the personal importance of exercise to them and their health. Later, the survey was translated by the researcher into Arabic, which is the language of the sample population (Appendix X).

The survey was tested for validity and reliability before data collection started to ensure that the results are acceptable in measuring what they intend to and consistent with producing the same results if conducted again in similar situations (Bolarinwa 2015). Validity was assessed with face validity as a subjective assessment of whether or not your study or test measures what it is supposed to measure (Bolarinwa 2015). The face validity was carried out among ten subjects who speak Arabic fluently. The participants read the questionnaire and reported anything misunderstood or if the questions are appropriate for the target audience. The participants reported several items that needed to be changed and constructed more appropriately. For example, initially the answers were on a 5-point Likert scale; however, most of the participants advised that there were too many choices and the answers were limited. Hence, the researcher changed the type of response or answers into three choices (e.g., No, Neutral or Yes). In addition, there were factors or questions with similar purpose which were merged to form a single question (i.e., perceived benefits of exercise and motivation by results). However, it should be noted that the face-validity was carried out on the Arabic translated questionnaire; thus, when the items of the questionnaire were translated, they could have resulted in similar interest or purpose.

Similarly, the questionnaire's reliability was carried out by a test-retest method using SPSS (Statistical Package for Social Sciences, version 25) software for Windows. Ten Arabic speakers participated in the reliability test, and the survey was completed two times, with five days between the first and second testing. The reliability was assessed with Fleiss Kappa (K) for categorical variables in each question, whereas K greater than 0 is considered an agreement between measures (Altman 1999; Eugenio and Glass 2004). Data were entered in SPSS as trial one and trial two; then, the Fleiss Kappa test was used to compare the two trials. The results showed the agreement ranged between moderate (K = .623, 95% CI [.128, 1.117], p < .001) to very good between the two measures (K = 1.00, 95% CI [.508, 1.492], *p* < .001). Thus, the survey has moderate to very good reliability.

Consequently, the questionnaire was used to evaluate the barriers and facilitators for physical activity in individuals with knee OA (Table 16). Participants filled in the questionnaires before physical fitness tests. The responses were displayed as percentages.

Table 16 Barriers and Facilitators to PA in individuals with knee OA survey

Questions	Choices		
How does your personality affect your decision to exercise?	◯ Negatively	◯ Neutral	◯ Positively
Does your self-image affect your decision to exercise?	◯ Doesn't affect	◯ Neutral	◯ Affect
How does your health condition affect your decision to exercise?	◯ Negatively	◯ Neutral	◯ Positively
How does your knowledge of physical activity and exercise, affect your decision to exercise?	◯ Negatively	◯ Neutral	◯ Positively
Does the enjoyment after exercising motivate you to continue exercising?	◯ Doesn't affect	◯ Neutral	◯ Affect
Does the results of exercising motivate you to continue exercising?	◯ Doesn't affect	◯ Neutral	◯ Affect

How does your experience with exercising affect your decision to exercise?	◯ Negatively	◯ Neutral	◯ Positively
How do you assess your knowledge of knee Osteoarthritis disease?	◯ Not enough	◯ Neutral	◯ Enough
Does the knee pain affect your decision to exercise?	◯ Doesn't affect	◯ Neutral	◯ Affect
Does the type of exercise affect your decision to exercise?	◯ Doesn't affect	◯ Neutral	◯ Affect
Does the quality of sleep affect your decision to exercise?	◯ Doesn't affect	◯ Neutral	◯ Affect
Does the knee stiffness affect your decision to exercise?	◯ Doesn't affect	◯ Neutral	◯ Affect
Does the family support affect your decision to exercise?	◯ Doesn't affect	◯ Neutral	◯ Affect
Does the physiotherapy support/ motivation affect your decision to exercise?	◯ Doesn't affect	◯ Neutral	◯ Affect
Does the physician support/ motivation affect your decision to exercise?	◯ Doesn't affect	◯ Neutral	◯ Affect
How does personal hygiene affect your decision to exercise	◯ Negatively	◯ Neutral	◯ Positively
How does the weather condition affect your decision to exercise?	◯ Negatively	◯ Neutral	◯ Positively
Does the availability of a training partner affect your decision to exercise?	◯ Doesn't affect	◯ Neutral	◯ Affect
How does the costs of accessing gyms or training facilities affect your decision to exercise?	◯ Negatively	◯ Neutral	◯ Positively
How do you assess the availability of exercise classes in your area?	◯ Not enough	◯ Neutral	◯ Enough
How does the access to transport affect your decision to exercise?	◯ Negatively	◯ Neutral	◯ Positively
How important is exercise and physical activity to you?	◯ Not important	◯ Neutral	◯ Important

How important is exercise and physical activity to your health condition?	◯ Not important	◯ Neutral	◯ Important*

* Neutral: can not be decided

3.4.2.9. Pain assessment

Pain severity was assessed by the numeric pain rating scale (NPRS) (Nahler and Nahler 2009; Hawker et al. 2011). It is a well-known tool that has been used frequently with a variety of populations. The validity and reliability of the NPRS are well documented in the literature as a valid and reliable measure of pain (Boonstra et al. 2008; Hjermstad et al. 2011). The NPRS consists of 11 ordinal scales that "0" represents "no pain" and "10" represents "extreme, unbearable pain" (Hawker et al. 2011); whereas scores from 1 to 3 are considered mild, 4 to 6 are moderate, and 7 to 10 as severe pain (Goulet et al. 2015). Participants in the knee OA group were asked to report the severity of knee pain at rest in the last 7-days by making a mark on the pre-designed scale (Hjermstad et al. 2011).

3.5. Data analysis

3.5.1. Type of data generated

The outcome measures produced quantitative data in the form of continuous numerical variables, categorical and ordinal variables (Table 17).

Table 17 Types of data generated

Outcome variable	Outcome	Type of data
Aerobic capacity	L/Min	Numerical Continuous
	Ml/kg/min	Numerical Continuous
	BORG	Ordinal
Muscle fitness	Nm/kg	Numerical Continuous
Muscle flexibility	Centimetres	Numerical Continuous
Balance	Seconds	Numerical Continuous
Body composition	BMI	Numerical Continuous
	BMI Category	Categorical
Age	Years	Numerical Continuous
Gender	Categorical	Categorical
Pain	NPRS	Ordinal
Physical activity	Total METS/week	Numerical Continuous
	PA category	Categorical
KOOS	Scores	Numerical Continuous
Barriers and Facilitators to PA survey	Percentage	Categorical

3.5.2. Data preparation

All the data from each testing procedure were recorded in a pre-designed form (Appendix F, Appendix G), then the raw data were entered into an Excel sheet. For the isokinetic dynamometer, sub-maximal exercise, Chair Sit and Reach and TUGT tests, the average scores of the tests were used for the analysis. Moreover, since aerobic capacity and muscle strength could be affected by body size and the participants' body composition, the scores were normalized by body weight (i.e. ml/kg/min and Nm/kg) to avoid this confounding factor. (Jaric 2002; American College of Sports Medicine 2017; Biodex Medical Systems Inc. 2017).

3.5.3. Statistical analysis

Statistical analysis was performed using SPSS (Statistical Package for Social Sciences, version 25) software for Windows. Descriptive statistics were used in the analysis of demographic and outcome measures. Continuous data with a normal distribution such as muscle strength, aerobic capacity, and balance were analysed with central tendency and dispersion measures, expressed as mean and standard deviation (Chan 2013)(Table 17). Moreover, continuous variables with non-normal distribution were analysed with median and inter-quartile range. Data from categorical variables such as PA category and BMI category were analysed with frequency measures and expressed as percentages (Chan 2013). Finally, ordinal data, such as the Borg scale, were analysed with median and inter-quartile range (Chan 2013).

An important step for deciding the measures of central tendency and statistical methods for data analysis is normality tests (Mishra et al. 2019). To elaborate, if data follow a normal distribution, parametric tests can be used; if not, nonparametric methods are used to compare the difference between groups (Mishra et al. 2019). Hence, for testing normality in our data, the Shapiro–Wilk test was performed for all variables, as it tests the null hypothesis that is the data distribution is equal to a normal distribution (Peacock and Peacock 2010; Ghasemi and Zahediasl 2012). Consequently, for normally distributed data ($p > 0.05$), the T-test for independent samples was used to compare the mean differences of variables between groups (Peacock and Peacock 2010; Chan 2013). For variables with non-parametric distribution with significance $p < 0.05$ in Shapiro–Wilk test, the Mann–Whitney test was used to compare the medians' differences between groups. The significance level was set at 5% (Fang et al. 2017b).

3.5.3.1. The rationale for Statistical Tests

At first, the researcher tested the assumptions for using an independent t-test for data analysis. To illustrate, six assumptions must be considered in order to run an independent-samples t-test (Sheskin 2011). The first three assumptions are related to the study designs;

the other three are related to the nature of the data. The first assumption is to have a continuous dependent variable, which are the outcome variables that had been measured in both groups. The second assumption is to have an independent variable which are the two groups (i.e. OA and non-arthritic healthy). Moreover, the third assumption is related to the independence of observations, which means that each group should include different samples that cannot be included in the other group. In this study, the groups were defined and divided by the presence of OA, which employ the third assumption.

The other three assumptions were tested in SPSS (Peacock and Peacock 2010; Sheskin 2011). First, there must be no outliers in the independent variables, which has not been met in this study as there were outliers in the data as assessed by inspection of a boxplot. Second, the independent t-test requires that all variables must be normally distributed, which was carried out by the Shapiro–Wilk test. The results show that this assumption has been violated in some variables ($p > 0.05$). The third is the assumption of homogeneity of variances, which was tested by Levene's test of equality of variances. The results also show that this assumption has been violated in several variables ($p < 0.05$).

Therefore, for variables that contain outliers and non-normal distributions, a non-parametric Mann-Whitney U test was used to analyze the data (Sheskin 2011; Ghasemi and Zahediasl 2012). The Mann-Whitney U is a non-parametric test with four statistical assumptions that must be met to run the test. The first three assumptions are related to the study designs; the fourth is related to the nature of the data. The first assumption is to have a continuous or ordinal dependent variable, which has been discussed previously as the outcome that had been measured in both groups. The second and third assumptions are about having an independent variable and independence of observations. The fourth assumption was tested in SPSS to evaluate the distributions of the group's variables, as it will show how the data will be interpreted. Variables distributions were evaluated by visual inspection of histograms. For data that has similarly shaped distribution, a Mann-Whitney U test was used to compare the medians of the dependent variables (Sheskin 2011; Chan 2013). If data distributions were shaped differently, the mean ranks score were used (Sheskin 2011). The p-value at < 0.05 was recognised as a statistically significant difference between groups. Table 18 is a summary of statistical tests used with outcome variables.

Table 18 Summary of statistical tests used with each outcome variable

Outcome variable	Outcome	Normal distribution	Statistical test
Aerobic capacity	L/Min	Normal	Independent t-test
	Ml/kg/min	Normal	Independent t-test
Muscle fitness	Nm/kg	Normal	Independent t-test
Muscle flexibility	Centimetres	Normal	Independent t-test
Balance	Seconds	Normal	Independent t-test
Body composition	BMI	Not normal	Mann-Whitney U test
Age	Years	Normal	Independent t-test
Physical activity	Total METS-min/week	Not normal	Mann-Whitney U test
KOOS	Scores	Not normal	Mann-Whitney U test

3.6. Ethical Considerations

Ethical approval was obtained from the School of Healthcare Sciences, Research Review and Ethics Screening Committee at Cardiff University on 15 June 2017 (Appendix H). Participants received the patient information sheet and consent form at least 24 hours (and up to a week) prior to data collection, which informed them about the nature and procedure of the research. All data were non-identifiable using the participant's anonymised research code, not their name nor hospital number. Participants were allowed to withdraw at any time without affecting their medical care or legal rights. Withdrawn participant's data were destroyed immediately. Anonymity and confidentiality were maintained throughout the study, in which the participants' identification was not involved during data analysis nor in the results. Based on the participant's interest and request, a summary of the research results might be sent to the participants through e-mail, phone or post.

No acknowledged health risks were found in the literature with the current protocol. This study did not include individuals with unstable angina. However, it did not exclude individuals with other co-morbidities; therefore, the safest and less risky sub-maximal exercise protocol was followed. In addition, pre-exercise screening and risk assessments were carried out in order to achieve optimum safety during the tests (American College of Sports Medicine 2017) (Appendix B, Appendix I). During exercise testing, the patient exertion was monitored with the Borg Perceived Exertion scale as well as the patient's hemodynamic. The participants were monitored at least 6 min after exercise testing or until resting data were obtained. Absolute and relative indications to stop the test were observed according to the American College of Sports Medicine (2017) criteria (Appendix I).

The researcher followed Cardiff University ethical procedures & Data Protection Act 2018. Therefore, all electronically recorded data were securely stored in the Cardiff University server. All questionnaires that were collected using a paper version were stored in a locked cabinet, within a lockable cupboard in the researcher's office at Cardiff University. All processing and analysis of data took place at Umm Al-Qura University. The researcher ensured that all personal data were securely held to prevent any unauthorised access or accidental loss. Personal data held separately to research data so nobody could be identified from the research data. The researcher ensured that all data was held securely throughout the process of reporting findings. Only the lead researcher had access to the data as appropriate for the analysis and dissemination. Research data would be stored for five years in line with Cardiff University research data retention policy. Patient-identifiable information such as contact details will be destroyed after one year of completion of the PhD.

4. Chapter 4: Results

The first phase of this study aimed to evaluate the difference in physical fitness and physical activity among knee OA individuals compared to non-arthritic healthy individuals. The results were be divided into four sections. The first section describe's the participant' characteristics and demographics, followed by a presentation of the findings from the KOOS questionnaire and NPRS. Then, the findings from the physical fitness and physical activity measurements in the OA and non-arthritic healthy groups, which were separated and presented according to each component of PF and PA. The last section integrated the PF and PA results.

4.1. Participant Demographics

A total of 54 subjects were enrolled in the study. Twenty-nine subjects were recruited in the OA group and 25 non-arthritic healthy participants in the comparator group (Al-Noor Hospital= 8 participants, Hera Hospital= 5 participants, UQU= 14 participants; 10 healthy and four knee OA individuals, social media= 27; 15 healthy and 12 knee OA individuals). All the participants completed all the tests and questionnaires, except 4 in the comparator group and 3 in the OA group, who could not complete the Isokinetic muscle test due to pain (2 in the OA group, and 1 in comparator group) or fatigue (3 in the comparator group and 1 in OA group). However, this did not affect the study findings as their missing data were managed statistically with SPSS software (e.g. Exclude cases analysis by analysis). Data on participant demographics are displayed in (Table 19). The non-arthritic healthy group consisted of 15 males and 10 females; on the other hand, whereas the OA group had 17 males and 12 female subjects. There was no statistically significant difference between groups for gender ($p= 0.920$). However, age was significantly different between groups ($p= 0.006$). The mean age in the non-arthritic healthy group was 53.4 years (SD ± 7.1); whilst, the mean age of the OA group was 60.1 years (SD ± 8.8).

Table 19 Participant demographics of the control and OA groups

Variable	Non-arthritic healthy (25 participants)	OA (29 participants)
Gender	15 (Male), 10 (Female)	17 (Male), 12 (Female)
Variable	**Non-arthritic healthy Mean (SD)**	**OA Mean (SD)**
Age	53.4 years (±7.1)	60.1 years (± 8.8)
Height	169.7 cm (±8.4)	170 cm (± 9.5)
Weight	91.3 kg (±18.2)	94 kg (±21)

4.2. Knee Osteoarthritis Outcome Score (KOOS)

The results of the KOOS score are divided into five subscales, as presented in Table 20. Data were collected from the OA group only, which show that OA participant appears to report several knee OA related problems. To elaborate, the results of the questionnaire may range between ‘0’ as severely affected and ‘100’, indicating no knee problems for each subscale. The findings in the level of pain and symptoms subscales had a median score of 53 (IQR ± 18) and 29 (IQR ± 18), respectively. While the activities of daily living subscale resulted in a median score of 62 (IQR ± 14), and the lowest scores were in the sports and recreation subscale, with a median score of 5 (IQR ± 19.5). Finally, the quality-of-life subscale had a median score of 31 (IQR ± 17.3).

Table 20 KOOS results

Variable	OA Median (IQR)
KOOS Pain	53 (± 18)
KOOS Symptoms	29 (± 18)
KOOS Activities of Daily Living	62 (± 14)
KOOS Sports and Recreation	5 (± 19.5)
KOOS Quality of Life	31 (± 17.3)

4.3. Numeric Pain Rating Scale (NPRS)

The results show that 28 participants with knee OA reported moderate to severe knee pain in the last 7-days (Figure 4). The percentage of participants with mild pain was 3.4% (1 participant), moderate pain 20.6% (6 participants), and the highest percentage reported severe pain, 76% (22 participants).

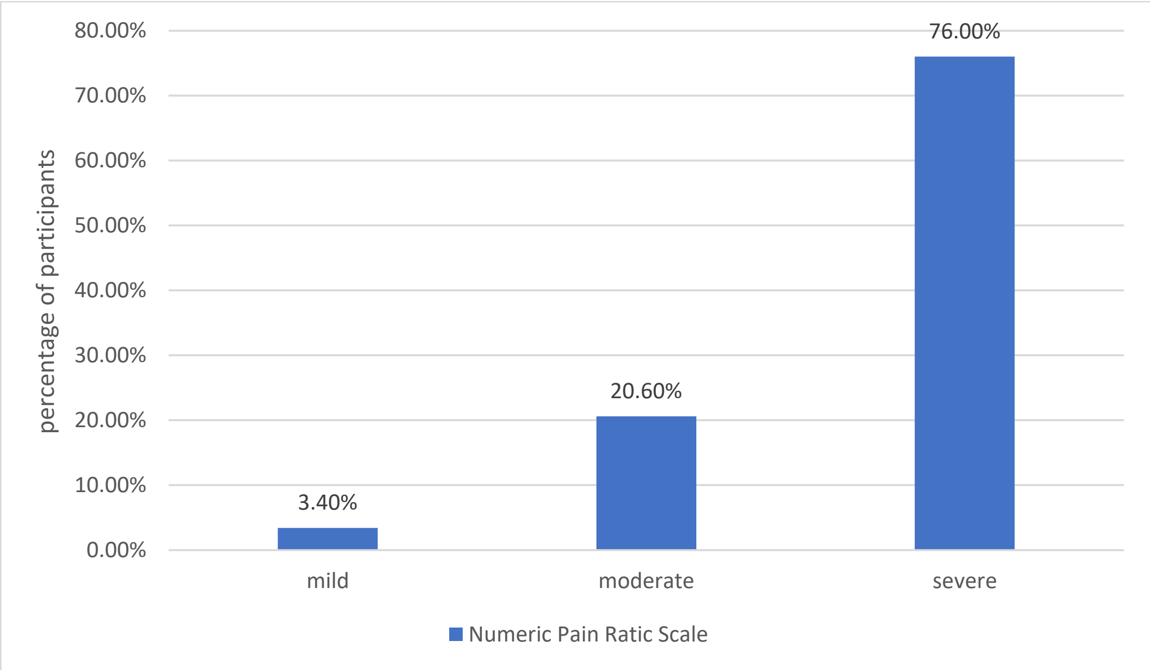

Figure 4 NPRS results

4.4. Physical fitness results

4.5. Body composition with BMI

As assessed by inspection of a boxplot, there were outliers in the data, and BMI scores for each group were not normally distributed, as assessed by Shapiro-Wilk's test ($p < 0.05$). Therefore, a Mann-Whitney U test was run to determine the difference between OA and non-arthritic healthy groups regarding BMI scores. The results show that the non-arthritic healthy group had a median BMI of 31.4 kg/m^2 (IQR± 7.2), and the OA group had a median of 32.1 kg/m^2 (IQR± 5.3). There was no statistically significant difference between the groups ($p= 0.652$).

Regarding the BMI category, a descriptive frequency statistic was used to determine the percentage of BMI category for the participants. Hence, both groups were mainly categorized as obese as data shows that 46.3% (25 participants) of the sample were classified as obese class 1, 20.4% (11 participants) classified overweight, 11.1% (6 participants) as obese class 2, 11.1% (6 participants) as obese class 3 and only 11.1% (6 participants) of the sample were categorised as having a healthy BMI. Group-specific data shows that non-arthritic healthy group BMI ranged from 23.44 kg/m^2 up to 46.99 kg/m^2, with 28% (7 participants) of participants classified as overweight, 36% (9 participants) obese class 1, 8% (2 participants) classified as obese class 2 and 16% (4 participants) obese class 3. Only 12% (3 participants) in the non-arthritic healthy group were classified as healthy BMI. Similarly, the OA group BMI ranged from 21 kg/m^2 up to 46 kg/m^2, with 13.7% (4 participants) were classified overweight, 13.7% (4 participants) obese class 2, and 6.9% (2 participants) obese class 3. While 55.17% (16 participants) of the OA group were classified as obese class 1, which was higher than the non-arthritic healthy group. Only 10.3% (3 participants) in the OA group were classified as healthy BMI (see Figure 5).

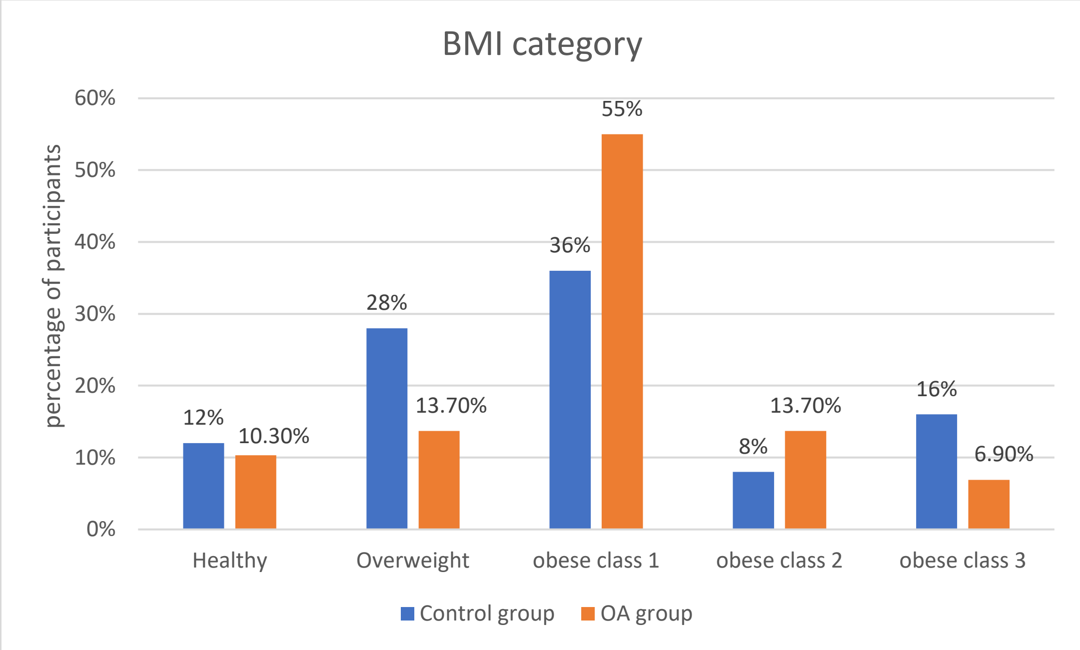

Figure 5 BMI category results for each group

4.6. Aerobic capacity

No outliers in the data were found as assessed by inspection of a boxplot, and the data were normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$). Hence, an independent t-test was used to determine the difference between the groups. All the participants in both groups were able to complete the sub-maximal aerobic capacity test. The recordings were calculated and analysed using the modified Astrand-Rhyming nomogram. The variables calculated were predictions of oxygen consumption that were expressed as absolute (L/min) and relative (ml/kg/min) VO2max. The results are displayed in Table 21, which shows that knee OA individuals had a statistically significant lower relative VO2max compared to non-arthritic healthy group (Knee OA; mean= 13.2 ml/kg/min (SD ± 6.3), Comparator; mean= 17.2 ml/kg/min (SD ± 7.2), p= 0.034). Similarly, the absolute VO2max results were also statistically significantly different between groups, which was lower in the OA group (Knee OA; mean= 1.20 L/min (SD ± 0.5), Comparator; mean= 1.49 L/min (SD ± 0.5), p= 0.038). All participants completed the test until the pre-determined 70% maximum heart rate was achieved.

Table 21 Aerobic capacity results

Variable	Non-arthritic healthy Mean (SD)	OA Mean (SD)	P-value
Vo2max (l/min)	1.49 (± 0.5)	1.20 (± 0.5)	0.038*
Vo2max (ml/kg/min)	17.2 (± 7.2)	13.2 (± 6.3)	0.034*

* Statistically significant results $P < 0.05$

4.7. Muscle fitness

An independent t-test was used, as the data were normally distributed with no outliers ($P > 0.05$). The overall results, as shown in the table (Table 22), are of 21 participants in the non-arthritic healthy comparator group and 26 participants in the OA group. Nevertheless, the findings indicate that muscle strength was statistically significantly different between groups as the OA group was found to have weaker muscles at 120°/second isokinetic concentric test; Hamstring (Knee OA; mean= .41 Nm/kg (SD ± .23), Comparator; mean=.63 Nm/kg (SD ± .25), p= 0.004); Quadriceps (Knee OA; mean= .63 Nm/kg (SD ±.33), Comparator; mean= .84 Nm/kg (SD ± .30), P= 0.008). There were no statistically significant differences between groups at 60°/second (Table 22). However, there were no significant differences observed in muscle fitness between the groups for the slower angular speed of isokinetic 60°/second. To elaborate, the findings of the comparator group in quadriceps had a mean of 0.91 Nm/kg (SD ± 0.46), while in the OA group, the mean was 0.76 Nm/kg (SD ± 0.44); (p= 0.155). Likewise, the hamstring muscle test in the comparator group had a mean of 0.53 Nm/kg (SD ± 0.15), while in the OA group, the mean was 0.46 Nm/kg (SD ± 0.20); (p= 0.171).

The isometric muscle tests revealed a statistically significant difference at most angles. For instance, mean isometric Quadriceps strength at a knee angle of 30° in the comparator group was 68 Nm/kg (SD ± 29.3), whereas in the OA group, the mean= 53.6 Nm/kg (SD ± 29.2), which was significantly lower than the comparator group (p= 0.42). Similarly, for the comparator group, isometric Hamstring strength at a knee angle of 30° was statistically significantly higher than the OA group (comparator: mean= 92.4 Nm/kg (SD ± 50.3), OA: mean= 66.15 Nm/kg (SD ± 39), p= 0.016). At knee angle of 40-degrees, the isometric hamstring and quadriceps strength was also higher in the comparator group compared to OA group (Quadriceps strength in comparator: mean= 92.3 Nm/kg (SD ± 52.6), OA: mean= 60 Nm/kg (SD ± 38.7), p= 0.012); (Hamstring strength in comparator: mean= 92.5 Nm/kg (SD ± 45.6), OA: mean= 67 Nm/kg (SD ± 35.4), p= 0.041). At knee angle of 50-degree, isometric Quadriceps was higher in the comparator group (mean= 97.7 Nm/kg; SD ± 47.7), compared to the OA group (mean= 69.6 Nm/kg (SD ± 41.2), which was statistically significantly different between groups (p= 0.011). a statistically significant difference was also found in isometric strength at the knee angle of 60 degrees, in which both, Quadriceps and Hamstring muscles were higher in the comparator group (Quadriceps strength in comparator: mean= 106 Nm/kg (SD ± 53.9), OA: mean= 76.9 Nm/kg (SD ± 52.2), p= 0.028); (Hamstring strength in comparator: mean= 80.8 Nm/kg (SD ± 35.5), OA: mean= 56.1 Nm/kg (SD ± 40.6), p= 0.023). However, isometric Hamstring 50° muscle test showed a non-significant difference between groups (Knee OA; mean= 59.3 Nm/kg (SD ± 34.9), comparator; mean= 79.2 Nm/kg (SD ± 37), p= 0.066).

Table 22 Muscle fitness results

Relative Peak torque (Nm/kg)	**Non-arthritic healthy comparator Mean (SD)**	**OA Mean (SD)**	**P-value**
Isokinetic Quadriceps 120°/second	0.84 (± .30)	0.63 (±.33)	0.008*
Isokinetic Hamstring 120°/second	0.63 (± .25)	0.41 (± .23)	0.004*
Isokinetic Quadriceps 60°/second	0.91 (± .46)	0.76 (± .44)	0.155
Isokinetic Hamstring 60°/second	0.53 (± .15)	0.46 (± .20)	0.171
Isometric Hamstring 30°	92.4 (± 50.3)	66.15 (± 39)	0.016*
Isometric Quadriceps 40°	92.3 (± 52.6)	60 (± 38.7)	0.012*
Isometric Hamstring 40°	92.5 (± 45.6)	67.7 (± 35.4)	0.041*
Isometric Quadriceps 50°	97.7 (± 47.7)	69.6 (± 41.2)	0.011*
Isometric Hamstring 50°	79.2 (± 37)	59.3 (± 34.9)	0.066
Isometric Quadriceps 60°	106 (± 53.9)	76.9 (± 52.2)	0.028*
Isometric Hamstring 60°	80.8 (± 35.5)	56.1 (40.6)	0.023*

* Statistically significant results P < 0.05

4.8. Balance and function

There were no outliers in the data, as assessed by inspection of a boxplot, and data were normally distributed, as assessed by Shapiro-Wilk's test (P > 0.05). Therefore, an independent t-test was used for the statistical analysis. The Timed Up and Go test was the outcome measure for testing the dynamic balance in individuals with knee OA used in this study. The results of this test are reported in seconds and compared between groups. Compared to the comparator group, the OA participants have used a statistically significant longer mean time to perform the test, which indicate a decrease in the dynamic balance (Knee OA; mean= 13.9 seconds (SD ± 2.9), comparator; mean= 10.5 seconds (SD ± 1.9), p<0.001).

4.9. Muscle Flexibility

First, no outliers were found, and normal distribution was evident in the data assessed by Shapiro-Wilk's test (P > 0.05) and inspection of a boxplot. The Chair Sit and Reach test was used to measure hamstring flexibility. The results are reported as the mean of minus or plus in centimetres (Table 23). Both limbs were tested, and compared the results between OA and the comparator group. The results show statistically significant evidence that individuals with knee OA have inferior hamstrings flexibility compared to non-arthritic healthy group (p<0.001).

Table 23 Muscle flexibility results

Variable	Non-arthritic healthy comparator Mean (SD)	OA Mean (SD)	P-value
Right Hamstring	-6.2 cm (± 8.9)	-19 cm (± 11.4)	< 0.001*
Left Hamstring	-7.6 cm (± 8.9)	-20 cm (± 14.3)	< 0.001*

* Statistically significant results P < 0.05

4.10. Physical activity level

Measurement of PA level was carried out by IPAQ-sf, which aimed to estimate the total METS-min consumed per week, then categorise PA level accordingly. There were outliers in the data, as assessed by inspection of a boxplot, and PA level for each group were not normally distributed, as assessed by Shapiro-Wilk's test ($P < 0.05$). Hence, the Mann-Whitney U test was used to determine the difference between groups for the PA level. First, the estimated total METS-min/week ranged in both groups from '0' as no reported physical activity and up to 5370 METS-min/week. The total METS-min/week in the non-arthritic healthy group ranged between 0 and 3375 with a median of 180 METS-min/week (IQR ± 671.4), while the OA group ranged between 0 and 5370 with a median of 66 METS-min/week (IQR ± 1264.6). Therefore, the Mann Whitney U test showed that physical activity levels were not statistically significantly different between OA and non-arthritic healthy ($P= 0.141$). Second, the results of the PA level category, which show that 90.74% (49 participants) in both groups were categorised as having low activity levels (Figure 6). Specifically, in the non-arthritic healthy group, 96% (24 participants) were considered as 'low activity' (0 to 1092 METS-min/week); likewise, 86.21% (26 participants) in the OA group (0 to 438 METS-min/week). Moreover, only two participants in the OA group were moderately physically active (1539 and 3358 METS-min/week); and one with a high level of activity (5370 METS-min/week). While the non-arthritic healthy group had only one participant with a high level of physical activity (4815 METS-min/week).

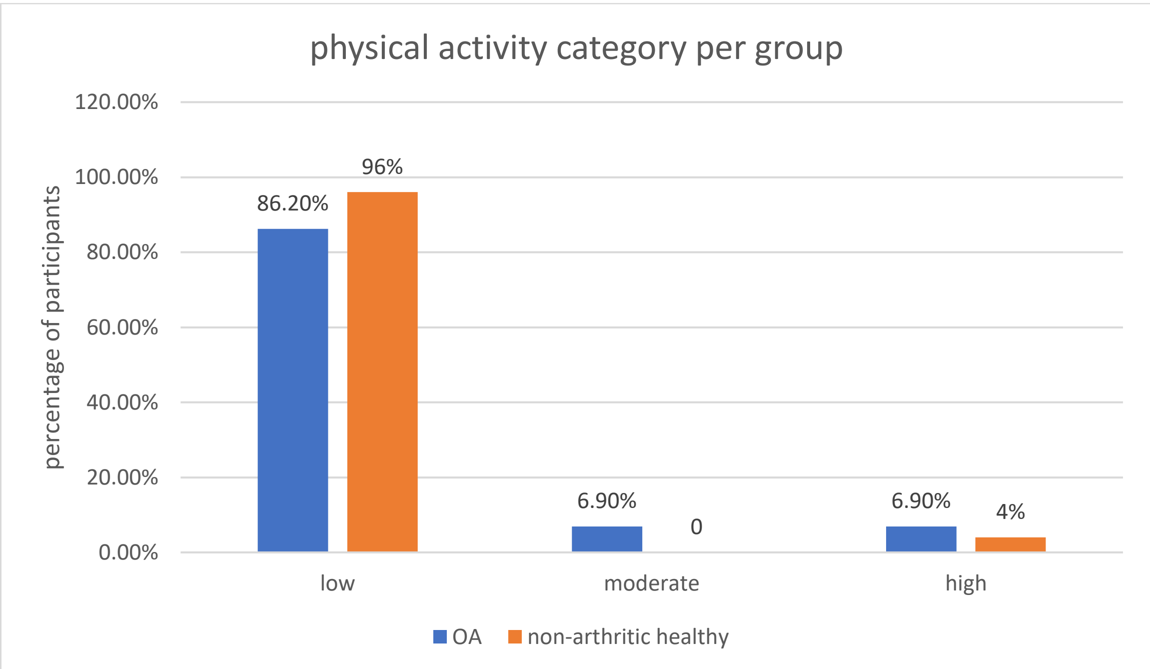

Figure 6 Physical activity category per group

4.11. Barriers and Facilitators to physical activity survey

One of this study's objectives was to survey the participant's barriers, attitudes, and experience towards physical activity. The survey had 24 questions exploring the barriers and facilitators to physical activity, which was reported by participants in both groups. The responses were displayed as numbers and percentages (Table 26), and they were presented in three sections: barriers to PA, facilitators to PA, knowledge and attitude towards PA.

4.11.1. Barriers to PA

In the OA group, nine barriers were commonly reported, while there were eight barriers reported in the comparator group. Beginning with the most commonly reported barriers, both groups reported weather conditions and lack of exercise classes in the area as major barriers to being physically active (OA: 82.8%; 24 participants, comparator: 88%; 22 participants). This was followed by the participants' health condition and knee stiffness that were the second most commonly reported barriers in the OA group (75.9%; 22 participants). Moreover, both groups also reported that their past experience and knowledge of exercise negatively affected their decision to exercise, which have been perceived as barriers (OA: 72.4%; 21 participants, comparator: 60%; 15 participants). In the comparator group, personal hygiene was reported by 56% (14 participants) to be a barrier to exercise. Next, personality and knee pain were common barriers in the OA group, reported by 62.1% (18 participants). Both groups reported the negative effect of the costs of gyms on their PA (OA: 51.7%; 15 participants, comparator: 44% 11 participants). The lowest reported barrier in the comparator group was personality and participants' health condition (48%; 12 participants).

Table 24 Barriers to PA (listed as most to least common barriers)

Knee OA group	**Non-arthritic healthy comparator group**
weather condition	weather condition
lack of exercise classes in the area	lack of exercise classes in the area
health condition	past experience
knee stiffness	knowledge of exercise
past experience	personal hygiene

knowledge of exercise	costs of gyms
personality	personality
knee pain	participants’ health condition
costs of gyms	

4.11.2. Facilitators to PA

There are several positive influencers or facilitators to PA that were found from the survey. For instance, transportation was found to be a positive motivation to exercise among both groups (OA: 51.7%; 15 participants, Comparator: 60% 15 participants). In addition, 75.9% (22 participants) of the OA group reported that personal hygiene positively affected their decision to exercise. Both groups reported that the type of exercise did not affect their participation in PA (OA: 72.4%; 21 participants, Comparator: 60%; 15 participants). Similarly, the quality of sleep does not affect the participants' decision to exercise (OA: 82.8%; 24 participants, Comparator: 88%; 22 participants).

Table 25 Facilitators to PA

Knee OA group	Non-arthritic healthy comparator group
transportation	transportation
personal hygiene	type of exercise
type of exercise	quality of sleep
quality of sleep	

4.11.3. Knowledge and attitude towards PA

Both groups had similar results on the lack of knowledge of knee OA (OA: 58.6%; 17 participants, Comparator: 44%; 11 participants). The participants' attitude towards PA in the OA group reported that it is not important for them (44.8%; 13 participants). Regarding family support and encouragement to exercise, 48% (12 participants) in the comparator group responded that family support does not affect their decision to exercise, likewise in the OA group (72%; 21 participants). Interestingly, 55.2% (16 participants) in the OA group reported that physiotherapy advice to exercise does not affect their decision to exercise, and 41.4% (12 participants) reported that physician advice was not encouraging them. At last, participants in both groups acknowledged that exercise and physical activity are important to their health (OA: 62.1%; 18 participants, Comparator: 56%; 14 participants).

Table 26 Barriers and facilitators to physical activity survey results

Question	**Negatively (Affect)**		**Neutral**		**Positively (Doesn't affect)**	
	Comparator	OA	Comparator	OA	Comparator	OA
How does your personality affect your decision to exercise?	48% (12)	62.1% (18)	16% (4)	13.8% (4)	36% (9)	24.1% (7)
How does your health condition affect your decision to exercise?	48% (12)	75.9% (22)	24% (6)	6.9% (2)	28% (7)	17.2% (5)
How does your experience with exercising affect your decision to exercise?	60% (15)	72.4% (21)	12% (3)	3.4%	28% (7)	24.1%
How does your knowledge of the importance of physical activity and exercise, affect your decision to exercise?	44% (11)	72.4% (21)	24% (6)	10.3% (3)	32% (8)	17.2% (5)
How does the costs of accessing gyms	44% (11)	51.7% (15)	16% (4)	17.2% (5)	40% (10)	31% (9)

or training facilities affect your decision to exercise?						
How does access to transport affect your decision to exercise?	24% (6)	37.9% (11)	16% (4)	10.3% (3)	60% (15)	51.7% (15)
How does personal hygiene affect your decision to exercise?	56% (14)	17.2% (5)	12% (3)	6.9% (2)	32% (8)	75.9% (22)
How does the weather condition affect your decision to exercise?	88% (22)	82.8% (24)	4% (1)	3.4% (1)	8% (2)	13.8% (4)
Question	Doesn't affect		Neutral		Affect	
	Comparator	OA	Comparator	OA	Comparator	OA
Does your self-image affect your decision to exercise?	44% (11)	62.1% (18)	16% (4)	6.9% (2)	40% (10)	31.0% (9)
Does the enjoyment after exercising motivate you to continue exercising?	52% (13)	79.3% (23)	12% (3)	6.9% (2)	36% (9)	13.8% (4)
Does the results of exercising motivate you to	68% (17)	69% (20)	8% (2)	3.4% (1)	24% (6)	27.6% (8)

continue exercising?						
Does the type of exercise affect your decision to exercise?	60% (15)	72.4% (21)	12% (3)	3.4% (1)	28% (7)	24.1% (7)
Does the quality of sleep affect your decision to exercise?	88% (22)	82.8% (24)	4% (1)	3.4% (1)	8% (2)	13.8% (4)
Does knee pain affect your decision to exercise?	52% (13)	27.6% (8)	24% (6)	10.3% (3)	24% (6)	62.1% (18)
Does the knee stiffness affect your decision to exercise?	56% (14)	17.2% (5)	12% (3)	6.9% (2)	32% (8)	75.9% (22)
Does the family support affect your decision to exercise?	48% (12)	72.4% (21)	20% (5)	17.2% (5)	32% (8)	10.3% (3)
Does physiotherapy support/ motivation affect your decision to exercise?	36% (9)	55.2% (16)	24% (6)	20.7% (6)	40% (10)	24.1% (7)
Does the physician support/ motivation affect your	40% (10)	41.4% (12)	20% (5)	31% (9)	40% (10)	27.6% (8)

decision to exercise?						
Does the availability of a training partner affect your decision to exercise?	44% (11)	27.6% (8)	28% (7)	37.9% (11)	28% (7)	34.5% (10)
Question	Not Enough		Neutral		Enough	
	Comparator	OA	Comparator	OA	Comparator	OA
How do you asses your knowledge of knee Osteoarthritis disease?	60% (15)	58.6% (17)	12% (3)	17.2% (5)	28% (7)	24.1% (7)
How do you asses the availability of exercise classes in your area?	88% (22)	82.8% (24)	4% (1)	3.4% (1)	8% (2)	13.8% (4)
Question	Not important		Neutral		Important	
	Comparator	OA	Comparator	OA	Comparator	OA
How important is exercise and physical activity for you?	28% (7)	44.8% (13)	36% (9)	37.9% (11)	36% (9)	17.2% (5)
How important is exercise and physical activity to your health condition?	12% (3)	3.4% (1)	32% (8)	34.5% (10)	56% (14)	62.1% (18)

4.12. Summary of phase 1 results

The study included 54 subjects recruited from Makkah city in Saudi Arabia. These participants were separated into two groups; twenty-nine subjects were recruited in the knee OA group and 25 non-arthritic healthy participants in the comparator group. The results showed that the OA group had several knee OA related problems on the five subscales of KOOS, and a high percentage of OA participants (76%; 22 participants) reported severe pain on NPRS. In addition, the results demonstrated a significant difference in PF components between knee OA individuals and non-arthritic healthy individuals in terms of aerobic capacity, muscle fitness (isokinetic strength at 120 angular velocity and isometric strength at 30, 40 50 and 60 knee angle), balance and flexibility, which were reduced in the OA group. Furthermore, the study did not find a statistically significant difference in the physical activity level nor in the body composition as the majority of participants in both groups were considered overweight/ obese with low physical activity level.

The barriers and facilitators survey results showed that the weather and lack of exercise classes are the most commonly reported barriers in both groups. Whereas a high percentage of the OA group reported that their health condition and knee stiffness were significant barriers to PA. Other common barriers reported in both groups were the lack of knowledge of the importance of exercise, with a negative experience with PA and the costs of gyms. Participants in both groups asserted that exercise is important for their health. The study also found several facilitators to PA in both groups, such as the availability of transport and personal hygiene. Whereas a wide range of responses were reported regarding the family, physician or physiotherapy support, which may indicate that social support may not effectively influence their decision to participate in PA.

5. Chapter 5: Discussion

The aim of this study was first to measure physical fitness and physical activity levels and to compare the findings with non-arthritic healthy individuals from a sample of individuals in Saudi Arabia. Data were collected on physical fitness components such as aerobic capacity, muscle fitness, balance, flexibility, body composition and physical activity level. In addition, data were also collected on the individuals' attitude about their knee health and problems, the severity of pain and barriers and facilitators to PA. The findings of the study suggest that several components of PF such as aerobic capacity, muscle fitness, balance and flexibility were significantly reduced in individuals with knee OA compared to non-arthritic healthy individuals. Whereas body composition, a PF component, was not statistically significantly different between groups with both groups, with individuals primarily being classified as overweight/ obese. In addition, several isokinetic outcomes were also not statistically significant between groups. The study also showed that both groups had low levels of PA, which could be associated with the identified barriers to PA, such as the weather, lack of exercise classes, health condition and lack of knowledge of the importance of exercise. The following sections discuss and interpret the results with the current literature, according to each aim and variable included in this study.

5.1. Subject demographics

Individuals who participated in this study were matched for gender, as no statistically significant difference was found between groups. There is a considerable amount of literature suggesting that OA is more prevalent in females compared to males. For instance, the female gender is considered one of the risk factors for developing knee OA (Kellgren and Moore 1952; Pereira et al. 2011; Hunter and Bierma-Zeinstra 2019). However, the included participants were evenly matched for gender; hence gender may not necessarily impact the study outcome.

Regarding age, although a considerable amount of effort was made to match the participants for age, there was a significant age difference between the groups, in which the OA group were older than the comparator group. This could be due to the limitation of the exclusion criteria of non-arthritic healthy participants with certain health conditions such as previous knee joint injury, contraindication to exercise tests or the use of walking aids, which meant that only younger individuals met the eligibility criteria. According to the literature, OA prevalence increases between the age of 50 and 75 years old (Järvholm et al. 2005; Moghimi et al. 2019). Hence, the mean age of OA participants in our study was 60.1 years, which falls into this age range. In addition, the average age of knee OA participants in the current study was similar to that reported by Brennan-Olsen et al.’s (2017) and Vårbakken et al.’s (2019a).

5.2. Patient-reported measures

5.2.1. KOOS

The outcome of the disease was reported with the KOOS questionnaire, which involves the ICF body function, activity and participation dimensions. The results demonstrated the effect of knee OA on five domains: pain, symptoms, function in daily living (ADL), function in sport and recreation and knee-related Quality of Life (QoL). In terms of the pain and symptoms domains, OA participants reported lower scores on these domains compared to the studies by Benner et al. (2019), Vårbakken et al. (2019a), Haverkamp et al.(2020) that had a similar population. Hence, it may suggest that the current study participants were experiencing comparably more pain and worse symptoms. For the ADL and quality of life domains, our results show that knee OA moderately (>50%) affected the individuals ADL, while their quality of life may be severely affected by the disease (mean= 32).

These ADL and quality of life domains findings were similar to the previous literature (Benner et al. 2019; Vårbakken et al. 2019a; Vårbakken et al. 2019b; Haverkamp et al. 2020). However, in the sports and recreation domains, the results showed a mean of 13.9 compared to 30 in Vårbakken et al.'s (2019a) and Benner et al.'s (2019) studies, and 41.4 in Haverkamp et al. (2020) study, which may suggest that our sample were more affected by knee OA as it severely reduced their participation in sports and recreation activities. The difference between our findings and the literature could be attributed to the fact that pain perception can be influenced by culture (Callister 2003; Campbell and Edwards 2012; Al-Harthy et al. 2016), and also to the social and environmental influence on PA (Gay et al. 2018).

5.2.2. Pain intensity

Participants graded the intensity of pain experienced in the last week with an 11-points Likert scale NPRS, which involves the ICF body function domain. The results showed that the majority of OA participants experienced moderate to severe knee pain. Thus, this study's findings were different from Vårbakken et al.'s (2019a, 2019b) studies, which had lower pain intensity in their OA Scandinavian sample on NPRS. However, the study by Alahmari et al. (2017) evaluated an OA population in Saudi Arabia and also found that the OA participants had severe knee pain on NPRS. Similarly, in Saudi Arabia, the pain intensity findings from Alghadir et al. (2018, 2016) show that the mean reported pain on NPRS was 5.9, which is categorised as moderate pain. The results of NPRS are similar to the KOOS-pain, which demonstrate a higher intensity and worse experience of pain compared to other studies from other countries.

This could confirm the previous findings on the cultural influence on pain perception (Callister 2003; Campbell and Edwards 2012; Al-Harthy et al. 2016), suggesting the subjective experience of pain and ethnic difference in pain tolerance that may vary between cultures (Rodrigues-De-Souza et al. 2016; Feng et al. 2017). However, the questionnaire relies on the participants' ability to recall, which may underestimate or overestimate the experienced pain based on the cognitive, social and contextual influences (Tripathi and Kumar 2014). Nevertheless, a high level of pain could be associated with lower physical fitness, quality of life, physical activity and function (Al-hazzaa 2018). To elaborate, pain has been recognized as a major barrier to the individuals' participation in physical activity, and it is the start of the inactivity cycle of knee OA (Osteoarthritis Action Alliance 2012).

5.3. Difference in physical fitness and physical activity between individuals with knee OA and non-arthritic healthy individuals

5.3.1. Physical fitness

In view of the ICF framework, most of the physical fitness components were used to assess the body function dimension, whereas the balance and aerobic capacity would also include the activity dimension. However, each PF component were discussed separately and later integrated at the end of this chapter.

5.3.1.1. Aerobic capacity

The evaluation of the submaximal exercise test on knee OA individuals has been inadequately explored in the previous OA literature, which may be due to concerns about participants' safety with disabilities (Noonan and Dean 2000; Sartor et al. 2013). Despite this controversy regarding the safety of applying exercise testing for individuals with chronic illness (Arena et al. 2007), in the current study, the sub-maximal exercise test was completed by all the participants in both groups. This could suggest that aerobic capacity testing is possible for individuals with knee OA, as it was safe for older adults who were overweight and physically inactive. Nevertheless, the results showed a statistically significant difference in the aerobic capacity measurement, which was lower in the knee OA group.

Despite the limited amount of literature, the findings were consistent with the previous studies that used maximal exercise test in individuals with knee OA (Minor et al. 1988; Minor et al. 1989; Philbin et al. 1995a; Philbin et al. 1995b), and 6MWT (Steffen et al. 2002; Stratford et al. 2006; Gomes-Neto et al. 2016; Baldwin et al. 2017; Cavalcante et al. 2015; Vårbakken et al. 2019a). However, studies that have used maximal exercise test were mostly outdated as recently the test was not recommended for individuals with disabilities (Noonan and Dean 2000; American College of Sports Medicine 2017); hence, the reliability of their findings is debatable. Similarly, the results of studies that used 6MWT may not reflect the aerobic capacity of knee OA individuals, as the test is more related to functional performance in meters rather than oxygen consumption (Steffen et al. 2002; Stratford et al. 2006; Gomes-Neto et al. 2016; Baldwin et al. 2017). To elaborate, the 6MWT aims to measure the distance covered in 6 minutes; then, this distance is used to compare the performance capacity in meters (Yázigi et al. 2018). In contrast, the submaximal cycle ergometer test is based on the linear relationship between heart rate, oxygen consumption and workload, which aim to monitor the heart rate and workload in order to predict the maximum oxygen consumption (Poole and Jones 2017). Nevertheless, none of the previous studies were carried out in Saudi Arabia, and this appears to be the first study that measured aerobic capacity in a sample of Saudi Arabian knee OA participants. Therefore, the findings would suggest that despite the published guidelines and advancements in the evidence-based practice that recommend the implementation of aerobic exercises in the physiotherapy treatment program (Bannuru et al. 2019; Kolasinski et al. 2020), individuals with knee OA in Saudi Arabia may still have a low aerobic capacity level. Hence, it may suggest that the adherence of clinical practice guidelines could be improved amongst physiotherapists in order to improve the aerobic capacity of knee OA individuals.

5.3.1.2. Muscle fitness

The statistically significant difference in quadriceps and hamstring muscles strength between knee OA and the non-arthritic healthy comparator group were consistent with the previous literature (Hootman et al. 2004; Alnahdi et al. 2012; Glass et al. 2013; Vårbakken et al. 2019b). The current results show that knee OA is associated with a reduction in muscle strength in quadriceps and hamstring muscles in isokinetic and isometric testing. Furthermore, in agreement with the previous literature in terms of the greater quadriceps strength compared to hamstrings (Lord et al. 1992; Patsika et al. 2014), our findings demonstrated similar results in both groups.

However, in our results, the isokinetic test at 60 angular velocities did not reveal significant quadriceps and hamstring muscle weaknesses, which does not agree with the findings of Hootman et al. (2004) and Vårbakken et al. (2019a; 2019b) that have used the same velocity. This difference between our findings and the literature could be explained by the participants' low PA levels and responses to the barriers survey, which suggests that our participants may lack familiarization with gym equipment such as the isokinetic dynamometer. In particular, in the isokinetic test, the participants are required to catch the machine to develop resistance in the range of motion; however, this may require a significant amount of familiarisation, especially with an unfit or experienced population

(Education and Biodex Medical Systems Inc. 2012). Hence, in the previous studies of Hootman et al. (2004) and Vårbakken et al. (2019a; 2019b), the participants carried out approximately five to eight isokinetic tests, which could suggest that their participants had more familiarization and a learning effect could be noticed.

In higher angular velocity (i.e. 120 angle/ second), our results show a significant difference between the OA and comparator. The literature shows that at slower velocities, the muscular moment generation capability and the imposed mechanical load is greater (Lockwood 1996; Dvir 2003). Furthermore, one of muscle contraction characteristics is the rate of force development as increased motor unit discharge rate, which is strongly associated with function and dependent on muscle size and strength, neural drive and pain (Maffiuletti et al. 2016; Rice et al. 2019).

Consequently, at the slower angular velocity that is believed to reflect muscle strength, the knee OA participants were able to contract the muscle with a force of development that is similar to the comparator group. Whereas at the faster velocity that is assumed to be a reflection of endurance (Biodex Medical Systems Inc. 2017; Hong et al. 2019), the rate of force development could be lower in the OA group, which could be due to the associated knee pain (Rice et al. 2019). Thus, the results may indicate that individuals with knee OA may have a significant muscle weakness that could be more noticeable in tasks that require a faster rate of force development, suggesting changes in neuromuscular function (Peñailillo et al. 2015).

5.3.1.3. Balance and function

As discussed in the literature on the components of PF, dynamic balance was one of the skill-related PF that was included in this study due to its alterations in individuals with knee OA. Nevertheless, the TUGT findings indicated that in the OA group, dynamic balance and function was significantly affected as the participants took longer to finish the test. The mean result of the TUGT of the OA group (13.9 seconds) was higher than the findings of Kim et al. (2011), which ranged between 8.4 to 11 seconds and Vårbakken et al. (2019a) that resulted in a mean of 6.5 seconds. Nonetheless, our TUGT results for the OA group were similar to those found in (Adegoke et al. 2012; Khalaj et al. 2014; Arora and Teli 2015; Moreira and Santos 2017) as the TUGT results of OA individuals in most of these studies ranged between 13.7 to 15.5 seconds. Therefore, the affected dynamic balance and function could explain the high percentage of falls among knee OA individuals reported in previous literature (Brand et al. 2005; Williams et al. 2010). Hence, the current results could also suggest that balance and function may be affected in OA individuals in Saudi Arabia, and they still could be at risk of falls (American College of Sports Medicine 2017).

Surprisingly, our comparator group results showed that they took extra time to finish the tests, with a mean of 10.5 seconds. Thus, when compared to the means of previous studies by Kim et al. (2011) and Vårbakken et al. (2019a), it may suggest an affected balance and function in our non-arthritic healthy participants as well. This could be explained by the other variables and components of PF; specifically, the low level of PA and high BMI results of OA and comparator groups which are believed to affect the individuals' balance and function (Herman et al. 2011; Marconcin et al. 2015). The results may suggest that the non-arthritic healthy population in Saudi Arabia, although they may not be at risk of falls, they could experience a general pattern of unfitness health complications.

5.3.1.4. Muscle flexibility

Flexibility is the joint's ability to move through a full ROM; it is an essential component of PF that maintains or facilitates daily activities and function and may prevent joint injuries (American College of Sports Medicine 2017). In our results, the hamstring muscle was significantly less flexible in the OA group than the non-arthritic healthy individuals. Thus, it may suggest that individuals with OA may have limited joint ROM in the lower limbs and reduced functional activities due to this low muscle flexibility. The current findings are consistent with the literature that showed lower muscle flexibility in individuals with knee OA compared to non-arthritic healthy individuals. For instance, the modified sit and reach test in Onigbinde's (2014) study also agrees with our results as it showed that the control group had better hamstring muscle ROM. Similarly, the flexibility examination with a goniometer in Shirazi et al.'s (2016) and Joshi and Yadav's (2019) studies also indicated the reduced hamstring flexibility in the OA group.

Since flexibility is linked with daily activities and function, our results could be explained by the results of low PA and low KOOS sports and recreation scores, suggesting that hamstring muscle flexibility could be related or affected by PA (Nuzzo 2020). In addition, in a recent study by Jarral et al. (2020), reduced flexibility was significantly associated with high BMI, suggesting that the reduced flexibility in our study could also be explained by the results of high BMI as well. Moreover, flexibility could be linked to the pain severity that found to be high in the OA group. To elaborate, evidence shows that individuals' pain threshold could significantly limit muscle flexibility that is aggrevated by joint movement (Nakatani et al. 2012; American College of Sports Medicine 2017). However, pain could also be a protective mechanism that inhibits the individual from overloading the joint to prevent further degeneration (Bennett et al. 2009). Hence, therapeutic exercises with optimal joint loading may reduce knee OA pain that could enhance the individuals' functional activities and improve the adherence to exercise (Susko and Kelley Fitzgerald 2013; Nicolson et al. 2018; Van Rossom et al. 2018).

Furthermore, flexibility was assumed to have an interchangeable relationship with muscle strength as low flexibility could limit muscle strength, whereas the lower strength could also be associated with low flexibility (Chaabene et al. 2019). Hence, the low hamstring flexibility results of the current study could be explained or linked with the results of low muscle strength in the OA group. However, the relation between muscle strength and flexibility is controversial, while there are studies that claim there is no correlation between them (Milliken et al. 2008; Dumith et al. 2010; Huang et al. 2018). Other studies demonstrated a correlation between muscle strength and flexibility (Tian et al. 2016; Nuzzo 2020). Nevertheless, none of the CPGs includes a therapeutic exercise to improve the flexibility of knee OA individuals. Therefore, the overall improvement in muscle strength, daily activities and function may not be achieved as long as this PF component is overlooked.

5.3.1.5. Body composition

Body composition was measured in the current study with body mass index (BMI). Consistent with the previous studies, our results show that the OA group was primarily categorised as overweight/obese (Cavalcante et al. 2015; Alahmari et al. 2017; Singer et al. 2018). However, our results also show that the majority of the comparator group were categorised as overweight/obese; hence, no statistically significant difference was found between groups. This non-significant difference may be similar to the studies by Bozbas et al. (2017), Vårbakken et al. (2019a; 2019b) and Mohammadi et al. (2008) as they also show that both groups were overweight/ obese. In contrast, our results may not be consistent with the previous studies by Onigbinde (2014) and Singer et al. (2018), as they show that the OA group was significantly overweight/obese compared to non-arthritic healthy individuals.

However, these findings could be a reflection of the sampled population, indicating that overweight/ obesity could be affected by culture, environment and lifestyle (Al-Hazzaa et al. 2012; Batsis and Villareal 2020). For example, in Mohammadi et al. (2008), the overweight sample was from Saudi Arabia, while the normal BMI was found in Bozbas et al. (2017) and Vårbakken et al. (2019a; 2019b) were from Turkey and Norway, respectively. Therefore, although the literature suggests weight loss as core management of individuals with knee OA (Bannuru et al. 2019), knee OA individuals may not see this as a priority in helping them manage symptoms or alter the course of their disease as the majority of the sample of non-arthritic healthy individuals were also overweight/obese.

Moreover, body composition is an important marker of the risk factors of knee OA and one of the PF components that were well-established in the literature. Specifically, high body composition as measured by BMI was associated with increasing the incidence of knee OA (Chaganti and Lane 2011; Silverwood et al. 2015; Tuttle et al. 2016). The lifetime risk for developing knee OA increases with the increase in BMI as it reaches up to 61% in individuals with a BMI of more than 30 (Murphy et al. 2008), and two out of three obese individuals may develop knee OA in their lifetimes (Osteoarthritis Action Alliance 2012; Arthritis Research UK 2019). Hence, our comparator group that resulted in a median BMI of 32 kg/m^2 could be at high risk for developing knee OA at some point in their life due to their high body composition and lack of physical activity that are recognized as risk factors for knee OA. Nevertheless, the current BMI results of both groups could be reflected in the results of low physical activity levels and low scores in KOOS Sports and Recreation, KOOS Activities of Daily Living in the OA group, which were discussed in detail in the following sections.

5.3.2. Physical activity level

Viewed from the activity and participation dimensions of ICF, physical activity level assessment with iPAQ-sf showed interesting findings, in which 90.74% (49 participants) in both groups were categorised as having low activity levels with no statistically significant difference between groups. The results of this study were similar to studies that used the accelerometer to measure PA. For example, in Thoma et al.'s (2018) study, the accelerometer measurement of PA between symptomatic knee OA and non-arthritic healthy individuals showed that both groups had a low level of physical activity. Similarly, in the Vårbakken et al. (2019a) study, the accelerometer results showed that the knee OA and control groups were considered to have low activity levels.

Nevertheless, the current study results were different from other studies that have used similar questionnaires, in which they found a significant difference between individuals with knee OA compared to non-arthritic healthy controls. For instance, in Herbolsheimer et al.'s (2016) study of PA level using the Longitudinal Aging Study Amsterdam Physical Activity Questionnaire (LAPAQ), the results showed that knee OA participants were significantly less active compared to healthy controls. Moreover, in Cavalcante et al. (2015) study of PA using IPAQ-sf, the results demonstrated that the OA group was physically inactive as they spent less time in PA than controls. This inconsistency and difference between the accelerometer and questionnaire studies in both our study and the literature may be due to the limitations of measures, as the literature shows that questionnaire responses could be affected by report errors, recall problems and social desirability (Sattler et al. 2020). Moreover, the inconsistency between our findings and other studies could be due to the population studied, as PA could be severely affected by the cultural attitude and social or environmental barriers (Al-Hazzaa et al. 2013; Sharara et al. 2018).

Existing evidence demonstrates that PA in individuals with knee OA could be severely affected by individual physical barriers due to their pain, joint stiffness and muscle weakness (Felson et al. 2007; Herbolsheimer et al. 2016; Timmermans et al. 2016). However, both of the groups in this study were inactive, which may suggest that not only individual barriers affect PA participation, but also social, environmental, and other contextual factors (Gay et al. 2018); and the low level of PA is a cultural problem associated not only with knee OA population. This could be confirmed by the studies that found similar

PA levels in the same population. For example, Al-hazzaa (2018) systematic review of PA in Saudi Arabia found that physical inactivity ranged between 26% to 85% among males and 43% to 91% among females. Moreover, in Al-Eisa and Al-Sobayel (2012), the findings from pedometer measurements of PA show a high level of inactivity among Saudi females.

5.3.3. Barriers and facilitators to PA

The barriers to PA in Saudi Arabia were explored using the developed barriers and facilitators survey. The survey involved an assessment of the environmental and personal factors of the ICF framework that could affect the other dimensions such as body function, activity and participation (World Health Organization 2001). The results show that, in general, there is an issue of lack of physical activity in the sampled population in both groups. The most common barrier reported in both groups was the weather, as some regions in Saudi Araba are known for incredibly hot weather, which did not motivate the participants to engage in PA. Several studies from different regions in Saudi Arabia also reported that bad weather was a major barrier for people to participate in PA (Amin et al. 2011; Al-Otaibi 2013; Al-Hazzaa 2018). Furthermore, in agreement with the previous literature (Al-hazzaa 2018), the lack of exercise classes and cost of the gym were reported to be a barrier for PA, which are believed to be the main places to participate in PA in Saudi Arabia (Serour et al. 2007; Rahman and Nahiduzzaman 2019; Alqahtani et al. 2020). On the individual level, the majority of the sample in both groups (OA: 58.6%; 17 participants, comparator: 44%; 11 participants) reported limited knowledge of the importance of PA. Furthermore, it shows that individuals with OA have limited knowledge of the disease, and 44.8% believed that PA is not important for them. The current study also found that both groups reported that personality and past experience with exercise were common barriers to PA. These findings agree with the previous literature as the lack of knowledge as well as previous experience are significant barriers to PA (Al-Kaabi et al. 2009; Petursdottir et al. 2010; Gay et al. 2019).

Although having a training partner, family support, and healthcare providers were addressed in the literature as facilitator or barrier to PA (Schutzer and Graves 2004; Petursdottir et al. 2010; Kanavaki et al. 2016), the findings show that family, physician or physiotherapist views did not influence the decision to exercise. Moreover, several studies have reported that transport was a barrier to PA (Serour et al. 2007; Al-Kaabi et al. 2009;

Al-Hazzaa 2018). Although a high percentage of participants (OA: 51.7%; 15 participants, comparator: 60% 15 participants) in the current study reported that transport was a facilitator for them to engage in PA; however, they are still physically inactive.

Regarding the low level of PA and the number of identified barriers to PA, there could be a need to consider frameworks such as the behaviour change wheel (BCW) to understand the population behaviour that could help in developing interventions to promote PA (Michie et al. 2014; Niedderer et al. 2017). To elaborate, BCW incorporates 19 theoretical behaviour change frameworks that could be used as behavioural analysis to understand the target behaviour, such as low PA level (Michie et al. 2014). The wheel consists of three components, capability, opportunity and motivation (COM-B model), which interact to generate behaviour. In this study, the BCW was used to understand PA's behaviour and the main barriers and facilitators to promote PA of OA patients and the non-arthritic healthy community. This would result in a number of intervention options to change the low PA levels of the target population.

Nevertheless, in line with views of the BCW, there are a limited number of physical, psychological, opportunity and motivational barriers to PA that were identified from the findings of this study, which could be targeted for interventions (Table 27). Consequently, the BCW suggests a number of interventions that could be used to change the low PA behaviour, such as education, incentives, environmental planning and regulations (Michie et al. 2014). However, due to the limitations of the close-ended survey that was as a method for collecting the barriers and facilitators to PA (Punch 2005; Creswell and Plano Clark 2017), there might be a need for an in-depth exploration of the barriers and facilitators to PA in individuals with knee OA and the non-arthritic healthy community. This would result in identifying a larger number of barriers and facilitators to PA that could be targeted for interventions with the BCW.

The current study findings were collected from a sample of knee OA individuals and non-arthritic healthy people. However, in order to understand and overcome the barriers and create opportunities for PA, the literature recommends the involvement of a variety of professions and stakeholders who may influence the behaviour (Derose et al. 2014; Webb et al. 2016; Lobelo et al. 2018). For example, physiotherapists are the healthcare profession concerned with providing PA and therapeutic exercises, and they may have a vital role in influencing and understanding PA of knee OA individuals. Hence, it is essential to involve different participants background or profession in the exploration of the barriers and facilitators to PA of knee OA individuals in Saudi Arabia, which could include physicians, physiotherapists, policy-makers and others.

Table 27 Behavioural diagnosis using the COM-B model (Michie et al. 2014)

COM-B components	Knee OA individuals	Non-arthritic healthy individuals
Capability- Physical	Individuals with knee OA are physically able to exercise limited by pain. However, many have reported that pain and stiffness were barriers for them to be active.	non-arthritic healthy individuals are physically capable of being active
Capability- Psychological.	Individuals with knee OA need to acknowledge the problem, increase their awareness about the benefit of physical activity, in addition to education about what type of exercise they can do. They lack motivation to exercise. The patients have reported that their fear of pain is a barrier to physical activity	non-arthritic healthy individuals believe in physical activity benefits, but they are not interested in or prioritizing this behaviour. There is a lack of awareness about the complications of physical inactivity.
Opportunity- Physical.	Individuals with knee OA need to be physically prepared before encouraging physical activity. Individuals with knee OA have the time to be active. However, the hot weather, transportation and	non-arthritic healthy individuals reported that hot weather, transportation and costs of accessing the gyms were barriers to physical activity.

	costs of accessing the gyms were barriers to physical activity	
Opportunity- Social.	Individuals with knee OA have reported that health practitioners support, family and friends do not motivate them to exercise.	non-arthritic healthy individuals reported that family and friends do not motivate them to exercise
Motivation- Reflective.	Individuals with knee OA need to understand the importance of increasing their physical activity. Individuals with knee OA experience that PA is painful. They have wrong beliefs about knee OA.	non-arthritic healthy individuals need to understand the importance of increasing their physical activity.
Motivation- Automatic.	Individuals with knee OA reported that pain and stiffness were barriers for them to be active. They are resigned to the disease.	non-arthritic healthy individuals, although they acknowledged the importance of PA, they lack interest in PA

Overall, evidence shows that PA is a significant component of the rehabilitation plan, which may be associated with enormous health benefits and a reduction in the associated disability (Penninx et al. 2001; Dunlop et al. 2005). Therefore, individuals with knee OA are encouraged to increase their PA levels to achieve these benefits. However, our findings showed that both knee OA individuals and the non-arthritic healthy individuals had low physical activity levels. Moreover, the findings from the barriers and facilitators questionnaire identified a limited number of barriers to PA, such as the hot weather, lack of exercise classes and past experience with exercises. In the views of the BCW, low PA behaviour could be influenced by physical, psychological capabilities and physical, social opportunity and reflective, automatic motivation (Michie et al. 2014). Considering the limitation of the questionnaire design to collect information regards PA, the findings on barriers of the low level of PA found in both groups was limited. Since PA is affected by the culture and environment (Al-Hazzaa et al. 2013), studies on PA in Saudi Arabia were in agreement regarding the lack of activity in the population (Al-Refaee and Al-Hazzaa 2001; Al-Nozha et al. 2007; Al-Eisa and Al-Sobayel 2012; Al-Hazzaa 2018). Hence, there is a need for a more in-depth exploration of the barriers and facilitators to PA in Saudi Arabia in the general population and individuals with knee OA from different participants perspectives to create effective strategies that could tackle this problem.

5.4. Integration of PF and PA results

Overall, the current study shows that some of the PF components and PA are affected in individuals with knee OA. In the OA group, there was a decrease in muscle strength, aerobic capacity, flexibility and balance. Whereas both groups were similar in body composition and PA levels, as they had low activity levels and were primarily overweight/obese. Although this study did not assess the correlation between PF and PA, Blair et al. (1989) and Chen et al. (2018) suggestion of the interchangeable relationship may agree with our findings since a reduction in PA could lead to a reduction of PF components, and vice-versa (Figure 7). Nevertheless, the current findings, in addition to the literature, may agree with the ICF framework's views, which suggests a dynamic interaction between functioning and disability. For instance, the affected PF components results that involve the body structure dimension in the ICF could be linked to the low PA level as activity participation dimension (a detailed discussion of the interaction between PF and PA were presented in this section)

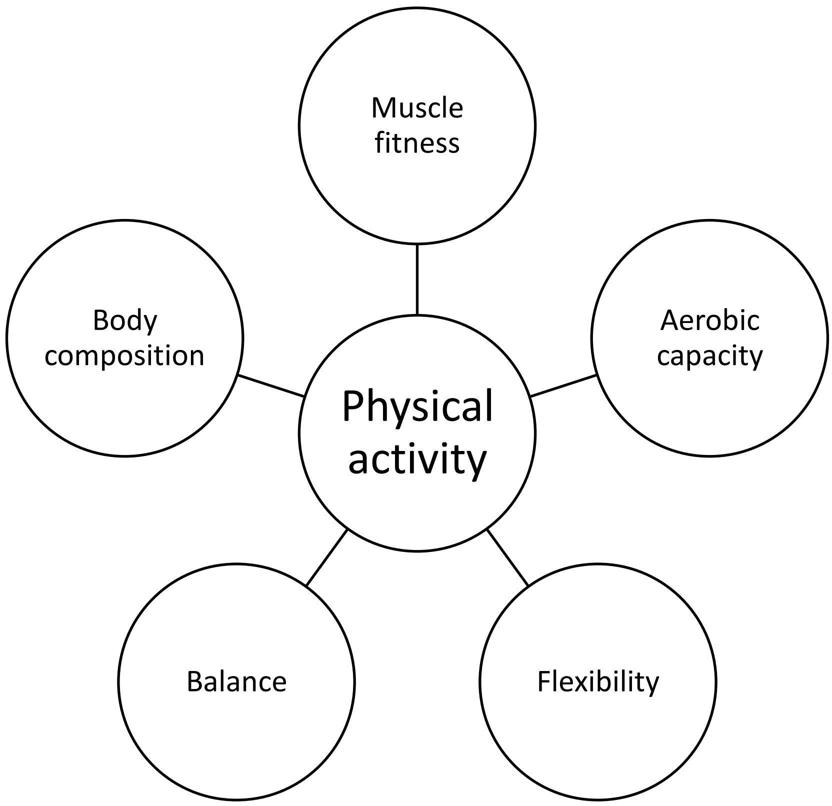

Figure 7 Interchangeable relationship between PF components and PA

Beginning with the first PF components; aerobic capacity, the literature shows that the reduced aerobic capacity could be due to lower muscle strength and physical activity and higher body composition (Fleg 1986; Conley et al. 2000; Lalley 2013). Evidence suggests that in obese older adults, there is a tendency to develop sarcopenia, which is characterized by reduced muscle strength and loss of skeletal muscle mass that in turn may lead to a decrease in physical activity (Tomlinson et al. 2016; Cruz-Jentoft et al. 2019). Consequently, obesity and activity limitation may also contribute to reducing the aerobic capacity (Tomlinson et al. 2016; Godziuk et al. 2018). Hence, our results regarding muscle strength, body composition, physical activity level, KOOS sports and recreation score, and KOOS ADL may agree with the previous literature that these factors could influence aerobic capacity. However, since both of our study groups demonstrated low physical activity levels and both groups were primarily overweight/obese (with no statistically significant difference between groups in these domains), the influence of aerobic capacity and body composition or physical activity was not evident in this study.

Nevertheless, their relationship was sufficiently addressed in the literature, in which a reduction in BMI would lead to a reduction of disability and knee OA symptoms, which in turn could improve physical activity level, resulting in improvements in aerobic capacity (Myers et al. 2015; Osteoarthritis Action Alliance 2019). Although aerobic capacity is an essential component of PF, it was specifically recommended as a core treatment in two recent clinical practice guidelines (Bannuru et al. 2019; Kolasinski et al. 2020), with no details on their parameters such as applicability, frequency, intensity or form. Therefore, it is vital to recommend and consider the specific aerobic exercise parameters in order to achieve the optimal effect of therapeutic exercise interventions, which could interrupt the cycle of activity in individuals with knee OA (Brosseau et al. 2017; Schulz et al. 2020).

Muscle fitness was found to be reduced in the knee OA group compared to the comparator group in the current study. The literature shows that muscle strength could be affected by the knee OA pain (Petterson et al. 2008; Luc-Harkey et al. 2018), in which individuals with knee OA may experience a fear of movement due to their pain, which may causes function and activity limitations (Santos and Gomes 2011; Chmelo et al. 2013). In addition, knee OA pain could also affect muscle strength by a reflex called arthrogenous muscle inhibition that is modulated through presynaptic and postsynaptic mechanisms in the damaged joint, which elicited by abnormal afferents that decreases the motor drive to muscles and limit muscle's generation force (Callaghan et al. 2014).

The reduced physical activity could lead to a decrease in muscle strength that is evident in osteoarthritic individuals (Luc-Harkey et al. 2018; Yázigi et al. 2018). Hence, this mechanism may explain the results of muscle weakness in the current study, in which the results of NPRS and KOOS pain scores demonstrated severe knee pain in individuals with knee OA. Nevertheless, although muscular strength was believed to decrease in individuals with knee OA as a result of pain and reduced activity (Felson and Chaisson 1997; Miller et al. 2013; Liow et al. 2017). The link between muscle strength and PA was not evident in the current study as both groups had low activity levels, while the OA group had lower muscle strength.

Moreover, the literature shows that quadriceps weakness was related to lower scores in functional measures such as KOOS, WOMAC, balance and aerobic capacity (Ekdahl and Broman 1992; Alnahdi et al. 2012). Consequently, this study's findings could indicate that each of the PF components may be linked to reduced muscle weakness in knee OA individuals, which may result in a reduced PA, function, and quality of life. However, there is evidence that muscle weakness contributes to the development and progression of OA that could be responsible for functional impairment (Englund 2010; Arden et al. 2014). For instance, quadriceps strength is related to the rate of loading, and individuals with weaker quadriceps may have higher loading that may initiate knee OA or cause progression of existing disease (Mikesky et al. 2000; Alnahdi et al. 2012). Therefore, the implementation of strengthening exercises in the treatment of knee OA is considered essential in order to reduce the load on the joint and disability, which would result in improvement in the functional activities of the individuals (Bennell and Hinman 2011; Coudeyre et al. 2016b). Nevertheless, the current CPGs do not provide specific recommendations on the type of strengthening exercise or details on exercise parameters for knee OA, which may indicate the lack of specific guidance for clinical practice.

The current study also showed that individuals with knee OA had statistically significantly lower dynamic balance compared to the comparator group. Therefore, considering the factors that would affect the dynamic balance and functional performance, such as muscle strength and pain (Hatfield et al. 2015; Takacs et al. 2015), our significant findings could be explained by the results of the reduced quadriceps and hamstring muscle strength as well as the NPRS and KOOS pain scores in individuals with knee OA. However, our findings may disagree with Mohammadi et al.'s (2008) results of the association between affected dynamic balance and increase in weight, in which both of our groups were similarly overweight or obese, but the balance was only affected in the OA group. Nevertheless, although it was addressed in the literature that flexibility and balance were affected in knee OA individuals, the CPGs do not describe the type of therapeutic exercises and interventions to improve flexibility and balance, which may not be applied for knee OA individuals. Consequently, individuals may still at risk of falls due to the affected balance, reduced strength, limitation in their ROM and functional performance.

5.5. Clinical implications

The findings of this study showed that PF components such as aerobic capacity, muscle fitness, balance and flexibility were lower in individuals with knee OA compared to non-arthritic healthy individuals. Whereas the current guidelines focus mainly on strengthening or aerobic exercises, and they do not provide a description of the type of exercise, frequency or intensity. Hence, the current findings may suggest that other PF components such as balance and flexibility could be included in the treatment plan and the need to include these studies and interventions in the clinical practice guidelines. Moreover, it could also indicate that clinicians are encouraged to improve their skills in evidence-based practice by looking for wider literature that is not included in the clinical practice guidelines.

This study indicated that despite the controversy regarding the safety of applying aerobic capacity testing for individuals with chronic illness (Arena et al. 2007), the sub-maximal exercise test was completed by all the participants in both groups. This could suggest that aerobic capacity could be safely assessed with a sub-maximal exercise test, as it was safe for the knee OA individuals as well as non-arthritic healthy individuals. The current findings of severe pain reported in the OA group could indicate a need for a better healthcare service for knee OA individuals living in Saudi Arabia and acknowledge the difficulties in the treatment associated with this pain intensity (Bennell et al. 2014). This could be achieved by applying pain-focused management that may consider the biopsychosocial model of pain, which involves interaction between the biological, psychological and social factors (Darnall et al. 2017).

Physical activity has been recognized as having enormous health benefits, and guidelines recommend people with knee OA engage in PA for at least 30 minutes of moderate-intensity exercise, five days a week, or 20 minutes of vigorous exercise for three days a week (Rausch Osthoff et al. 2018). However, the low PA levels observed in both groups of this study may indicate cultural barriers and negative attitudes towards PA, which may indicate the need for healthcare providers to include recommendations for promoting PA in their clinical practice. Moreover, the findings in line with the views of the BCW may suggest the need for in-depth exploration of the barriers and facilitators to PA in Saudi Arabia with a variety of participants that could result in identifying a number of barriers that may affect PA behaviour.

5.6. Limitations

There are several limitations in the study sample or the methodology. For example, in the study sample, the statistically significant age difference between OA and non-arthritic healthy comparator group may be considered a limitation as the OA group was older than comparator. However, this could be due to the eligibility criteria that aimed to recruit participants with non-arthritic healthy lower limbs with no knee pain; hence, it was challenging to find older adults without any disabilities in the lower limbs. Regarding the methodology limitations, the aerobic capacity assessment was based on a prediction rather than actual measures, which is subjected to overestimation or underestimation of the participants VO2max (American College of Sports Medicine 2017). However, the use of prediction of VO2max was due to the lack of availability of actual measures instrument (e.g., MetaMax 3B indirect calorimetry), which could have been more valid and reliable in measuring aerobic capacity. The study did not distinguish the level or phenotypes of knee OA individuals which may be considered as a limitation as well. In addition, although the study followed ACSM (American College of Sports Medicine 2017) sequence for physical fitness assessment, and participants were given time to rest between the tests, the number and sequence of tests might have affected the outcomes as fatigue could be have been noticed and the tests scores could have been reduced.

Furthermore, although we had similar results with accelerometer studies in PA, the questionnaires are limited to individual perception, interpretation of the question and recall bias, as they could underestimate (Maddison et al. 2007; Prince et al. 2008; Rush et al. 2008) or overestimate (Koebnick et al. 2005; Mahabir et al. 2006; Prince et al. 2008) physical activity. The developed barriers and facilitators to physical activity survey may have several limitations as well. Therefore, the use of other available pre-developed, validated, and reliable questionnaire such as Perceived barriers to and facilitators of physical activity in people with knee osteoarthritis (Coste et al. 2020) could be superior. It is acknowledged that the study findings may be limited to the city in which the study was carried out.

5.7. Recommendations

The results of this study indicate the following recommendations to the healthcare practice and research in Saudi Arabia. Firstly, the comprehensive assessment of PF in knee OA sample from Saudi Arabia indicated that the OA population have low aerobic capacity, muscle fitness, balance and flexibility compared to non-arthritic healthy individuals. This may suggest the need to consider each PF component in the treatment plan, such as flexibility, balance, aerobic, strength and weight loss exercises. Secondly, the low PA level found in both groups of this study may indicate cultural barriers and negative attitudes towards PA that could be understood with behaviour theories such as the BCW, which indicated that behaviour is influenced by capabilities, opportunities and motivational factors. Hence, it requires an in-depth exploration of the barriers and facilitators to PA in Saudi Arabia from different participant's perspective who can influence PA behaviour and create effective behavioural interventions. Thirdly, further exploration of the healthcare system for managing knee OA is recommended to understand the strategies to address PF and PA as part of the treatment plans.

6. Chapter 6: Conclusion

The first phase of this study aimed to evaluate the difference in in physical fitness and physical activity among knee OA individuals compared to non-arthritic healthy individuals. Overall, the results showed that PF components in the OA group were lower than the comparator group. Moreover, several findings need further explanation and exploration with more appropriate methods. In particular, the results show that there was no significant difference between both groups in terms of BMI (both groups were overweight) and physical activity (both groups were low active). In addition, most of the sample (OA and non-arthritic healthy) showed a limited number of barriers to physical activity and exercise. Osteoarthritic individuals, as discussed earlier in the literature chapter, are more likely to be physically inactive and overweight due to their pain and disability compared to the non-arthritic healthy subjects, and they are expected to be receiving advice for lifestyle modification and increasing their physical activity as the guidelines recommend. However, finding that both groups were overweight, inactive with several identified barriers to PA could indicate that wider beliefs and cultural factors may influence population attitudes towards PA, causing a lack of activity. Therefore, it is vital to explore and understand the behaviour, attitude and barriers to physical activity in Saudi Arabia from different participants' experience and perspective to tackle the problem and avoid the health costs associated with inactivity. In addition, there is also a need to understand how physiotherapists use evidence-based practice in the treatment of OA. Hence, a second phase was carried out, which took the form of qualitative design, and the quantitative phase 1 was joined with a qualitative phase 2 in a mixed-method sequential design.

7. Chapter 7: Emergent mixed methods

The current findings of the low level of PA in both groups and the limited number of identified barriers to PA indicated that PA could be a cultural problem in Saudi Arabia, which needed explanation and in-depth exploration of the Saudi population attitude, experience and barriers to PA. Therefore, the second phase of this study had to be carried out by using a qualitative design, so the overall study developed into a mixed-methods design.

Mixed methods research design has evolved since it was first defined by Greene et al. (1989), in which they state that mixed methods designs include one quantitative and another qualitative method, where they are not linked to any paradigm. Many years later, Creswell and Plano Clark (2017) defined mixed methods as research that include specific core characteristics; it must collect and analyse quantitative and qualitative data that are combined in the results to demonstrate a deeper understanding of the research questions. Furthermore, it must form a logical research design and procedure within philosophy and theory. Mixed methods designs were believed to be of high value since they provide the opportunity to explain quantitative results (Terell 2012). Borkan (2004) stated that mixed methods would expand the toolbox and provide the investigator with additional perspectives and insights that no other method would offer. Moreover, Stockman (2015) believed that this design would increase students' opportunity to become self-sufficient, independent researchers. However, as the case with every research design, mixed methods also have limitations. Notably, the research's time frame, as it needs a considerable amount of time to complete the two phases of the study (Creswell and Plano Clark 2017).

7.1. Justification for the mixed-method design

This inquiry method was found to be the most suitable method for addressing the research questions and aims. **First**, there was a need to measure the physical fitness and physical activity levels in individuals with knee OA, as highlighted in the literature. This would be in the form of collecting quantitative data on PF and PA levels. Creswell and Plano clark (2017) suggest that a quantitative method is most appropriate if the research seeks to understand the difference between two groups; indeed, the OA group was compared to the non-arthritic healthy comparator group. **Second**, the results of the first phase informed the second phase of the study. Specifically, the lack of PA in both groups and the limited number of identified barriers to PA, which needed explanation in terms of their attitudes and experience with PA. This was achieved with a qualitative method in the form of semi-structured interviewing using purposive sampling in Saudi Arabia. However, since the choice to carry out a mixed-methods design was not intended at the beginning of this research, the emergent mixed method was carried out due to the results of phase one of this study. Nevertheless, mixed methods research design was believed to provide a more detailed, deeper and broader picture of the barriers to PA in the OA and non-arthritic healthy population in Saudi Arabia and the healthcare providers to promote PA. A representation of Creswell and Plano clark (2017) Mixed Method Sequential Explanatory Model is illustrated in Figure 8.

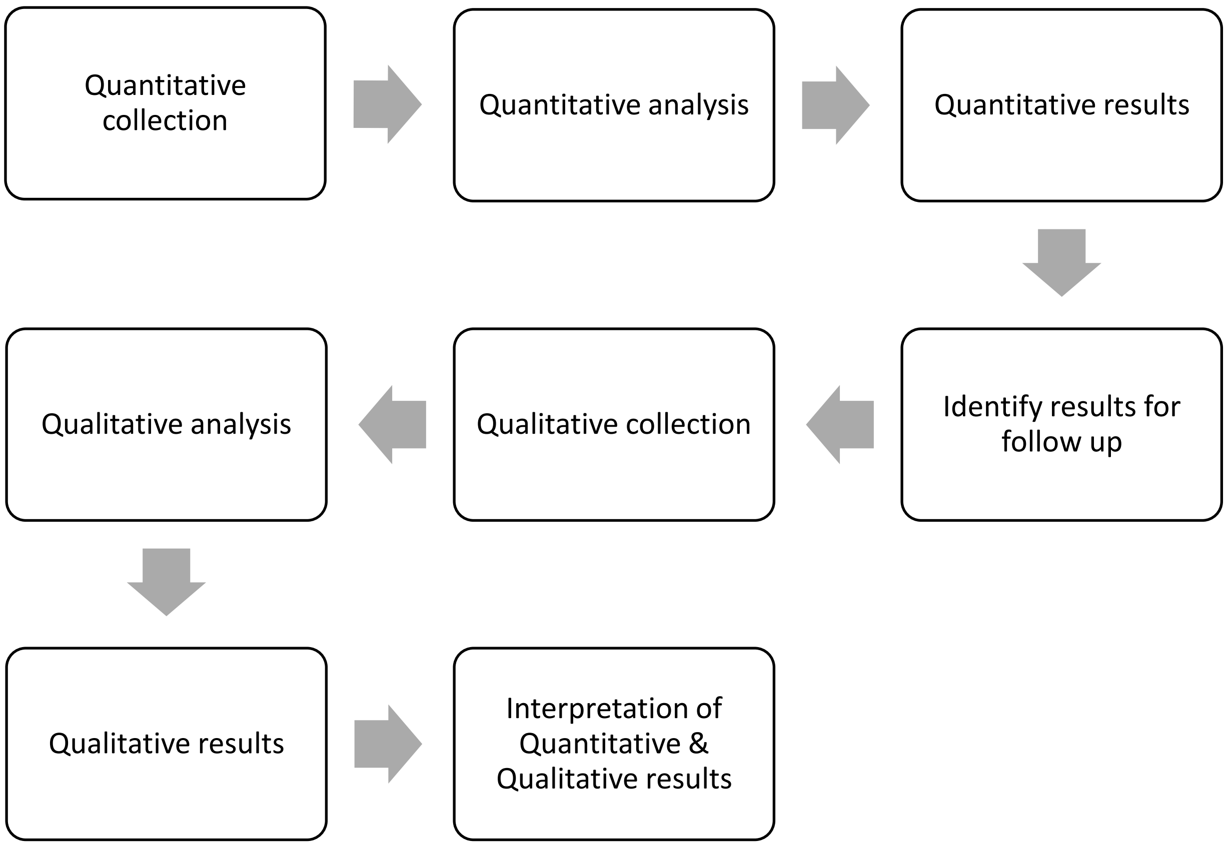

Figure 8 Mixed Method Sequential Explanatory Model, combiled from Creswell and Plano clark (2017)

Phase 2: Participants perspectives on opportunities, barriers to physical activity, and healthcare delivery for individuals with knee osteoarthritis

8. Chapter 8: Brief literature review

8.1. Introduction

There is a considerable amount of literature and consensus on the health benefits of regular physical activity and its effects on the quality of life, countries' economies, and society (Holm et al. 2015; Rausch Osthoff et al. 2018; World Health Organization 2020). However, the first phase of this study found the low level of PA in both groups and the limited number of identified barriers to PA. This could indicate that PA could be a cultural problem in Saudi Arabia that could be related to the population resources, behaviour and understanding of the importance of PA. The previous literature review also shows that Saudi Arabia's population is considered physically inactive (World Health Organization 2016). Moreover, there were several barriers to PA in the non-arthritic healthy populations, such as lack of time and appropriate place, especially in females, the lack of facility and resources, urbanization, traffic, scorching weather, lack of social support (Al-hazzaa 2018). Hence, the findings of phase one and the literature may indicate that the change towards promoting PA in OA individuals as part of their treatment plan could be challenging.

Therefore, behavioural strategies such as the BCW could be used to understand the behaviour of individuals with knee OA in order to ease the promotion of PA by physiotherapists. The BCW requires consideration of several factors such as the individuals' capability, opportunity and motivation (COM-B model), which interact to generate behaviour (Michie et al. 2014). For instance, the Saudi Arabian population's PA behaviour would be affected by the physical and psychological capabilities, the physical and social opportunities, and automatic, reflective motivation to engage in PA (Michie et al. 2014; Gay et al. 2016). However, the first phase of this study resulted only in a limited number of PA barriers, which suggested the need to consider an in-depth exploration of these factors (COM-B model) to understand and create strategies to promote PA in the Saudi population. In addition, in line with the views of the BCW, PA could be influenced by the social and physical opportunities that may reflect social support and resources (Serour et al. 2007;

Michie et al. 2014). This would suggest that a variety of professional or stakeholders such as policymakers, healthcare providers, school teachers, and the community itself could significantly influence PA as part of the treatment plan for knee OA individuals (Derose et al. 2014; Webb et al. 2016; Lobelo et al. 2018).

For instance, healthcare providers play an essential role in promoting PA in the community. Several strategies have been recommended, including PA counselling, behaviour change and education within the healthcare context (Lobelo et al. 2018). For example, the United States has a national physical activity plan, which developed strategies aimed to prioritise the efforts in healthcare to promote PA by recognising physical inactivity as a preventable and treatable condition and partnering across sectors to improve access to PA related services and expanding education on PA in the training of all healthcare professionals (U.S. National Physical Activity Plan Alliance 2016). In Saudi Arabia, there is also a strategy to promote PA in the community and patients, which involves healthcare providers (Ministry of Health 2014). However, the strategy does not provide details on the recommendations that should be followed, nor include coordinated bodies or provided resources and guidance for healthcare providers.

Nevertheless, studies have shown that healthcare providers may face barriers to promoting PA, such as the lack of training, resources, limited counselling time, and high workload at their clinics (AuYoung et al. 2016; Kime et al. 2020). A Saudi Arabian study shows that although the primary healthcare providers routinely discussed PA at their clinics, they also demonstrated similar barriers, and they further added the lack of financial support, protocols and patient cooperation (Al-Ghamdi et al. 2018). Therefore, the efficacy of such strategies to promote PA might be questionable and may need further development to increase the implementation within the healthcare context (Albert et al. 2020). Physiotherapists might be the healthcare profession concerned with improving PA (Fowles et al. 2018; Tuna et al. 2020) and provide therapeutic exercise as a core treatment for individuals with knee OA (Bannuru et al. 2019). However, studies on their efforts in promoting PA show an inconsistency in providing PA advice, lack of knowledge of PA guidelines, with lack of protocols that guide the physiotherapists towards promoting PA (Lowe et al. 2017; Lowe et al. 2018). Moreover, healthcare practice could be affected by the environment, resources, culture, and healthcare provider qualification (Mannion and

Davies 2018; Correa et al. 2020). However, none of the previous studies explored physiotherapy practice and their attitude towards promoting PA in Saudi Arabia.

8.2. The gap

The literature review and the results of the first phase of this study showed that the PA level in the sample of knee OA and non-arthritic healthy population in Saudi Arabia was low, with a number of barriers to PA. A large and growing body of literature, in addition to the first phase of this study, has identified several barriers to PA in knee OA individuals (Petursdottir et al. 2010; Dobson et al. 2016a; Gay et al. 2019) and a non-arthritic healthy population in Saudi Arabia (Amin et al. 2011; Al-Otaibi 2013; Al-Hazzaa and AlMarzooqi 2018), which may make the change towards promoting PA in OA individuals more challenging. Moreover, this could indicate that low PA levels could be a cultural problem in Saudi Arabia. In line with the views of the BCW, PA behaviour could be influenced by capability, opportunity and motivation, which was limitedly explored in the first phase of this study. Hence, there is a need to understand individual perspectives on PA barriers from the non-arthritic healthy population and knee OA individuals with more in-depth methods to tackle the low level of PA problem.

The literature also showed that physical activity as a behaviour of knee OA individuals is influenced by social support and resources and suggested the involvement of different professional perspectives, such as healthcare providers, in the strategies that aim to promote PA (Alahmed and Lobelo 2018; Lobelo et al. 2018). In addition, the clinical practice guidelines of knee OA agreed that OA individuals are advised to receive PA education as core treatments (Kolasinski et al. 2020). However, the findings of phase 1 indicated that physiotherapists nor physicians affected the sample of knee OA individuals and non-arthritic healthy individuals decisions to participate in PA. Hence, the healthcare outcome in terms of improving pain, PF and PA levels of knee OA individuals may not be achieved if PA advice is not implemented.

Furthermore, previous evidence shows that healthcare providers may face several barriers to promote PA (AuYoung et al. 2016; Kime et al. 2020), while physiotherapists might be the healthcare profession concerned with improving physical activity in knee OA individuals. However, evidence-based physical therapy practices with knee OA individuals in Saudi Arabia has had limited exploration, with a lack of research exploring management protocols and the adherence to CPGs. Hence, it is also recommended to explore the physiotherapists' attitude towards the guidelines to understand the implementation barriers in Saudi Arabia. The findings could provide an evidence base for ways to improve adherence to the guidelines that could enhance the quality of service and promote PA in knee OA individuals.

9. Chapter 9: Methods (Phase two)

As a mixed-method design, the second phase of this study was qualitative in the form of semi-structured interviews, which aimed to explain the results of the first phase and answer the research questions related to the low level of PA, barriers and facilitators to PA, and explore the physiotherapists' barriers and attitude towards the guidelines in Saudi Arabia.

9.1. Design rationale

A qualitative approach was used to enable the participants to express their opinions and perspective that could explain the results of phase 1 on the management of knee OA and the lack of physical activity. Qualitative research uses a range of methods, paradigms and approaches to data analysis (Creswell 2013), aimed to guide the understanding of individuals from their own opinion, perspective and experience that helps to describe, predict and explore a phenomenon (Taylor et al. 2016). Data analysis using a qualitative design is an inductive process that develops theories and concepts from patterns in the data to build a theory that is embedded in the data (Taylor et al. 2016). Moreover, the qualitative analysis aims to find themes and categories to develop an in-depth understanding from the participant’s perspective (Flick 2014). The data gathered from qualitative research often involve words or images rather than numbers, as is the case for quantitative research (Ritchie et al. 2014).

One of the common characteristics of qualitative research is that the data are rich, detailed and complex (Ritchie et al. 2014); this would allow the researcher to have an in-depth insight into the view of the participants, that may not be achieved through a quantitative approach (Punch 2005). Ritchie et al. (2014) have proposed four functions of qualitative research as; Contextual, that is aimed to describe the nature of what exists; Evaluative, which searches for the effectiveness of what exists; Generative function that aids in developing theories and strategies; Explanatory, which examines the reasons for a problem or to find an association between two issues. Since the second phase of this research aims to explain the findings of the first phase, the explanatory function of qualitative research was adopted. The explanatory purpose would be to study the participants' decision, behaviour, and attitude towards the barriers and lack of PA (Ritchie et al. 2014).

There are four main data gathering methods for qualitative research: observation, focus group, in-depth interview, and semi-structured interview (Ritchie et al. 2014; Lichtman 2017). The choice method depends on three factors; the nature of data, the subject matter and the population (Lichtman 2017). Since this qualitative phase aims to explain the results of phase 1, the interview was found to be the most appropriate method. Ritchie et al. (2014) demonstrated that, first, the nature of the data in the interview would aid in providing in-depth personal information of the participants, an understanding and exploration of their experience in the management of knee OA, as well as their attitudes and barriers to physical activity. Secondly, interviews would allow the researcher to explore the experience, motivation and barriers towards phenomena. Finally, considering that the research is mainly explaining and exploring the participant's attitude to the management guideline and their barriers to physical activity, the participants may not be able to share their attitudes, barriers and personal lifestyle issues in groups as it may be a sensitive topic (Kitzinger and Barbour 1999). Therefore, one-to-one interviews are assumed to be the best choice for collecting qualitative data for the second phase.

9.2. Worldviews

It has been maintained that qualitative research must have a philosophical foundation and assumptions that shape the research plan and aims (Creswell and Plano Clark 2017). Those philosophical assumptions are known as worldviews or paradigms. Worldviews are defined as a 'set of generalisations, beliefs and values of a community of specialists'(Creswell and Plano clark 2017, pp. 35). A number of worldviews are available in the literature based on the nature of the research and inquiry type. However, according to Creswell and Plano clark (2017), the four most common and useful worldviews for mixed methods research are; postpositivist, constructivist, transformative and pragmatist. Others argue that pragmatism is the only mixed-methods worldview appropriate for thesis studies (Johnson and Onwuegbuzie 2004; Shannon-Baker 2016). Nevertheless, the postpositivist worldview is associated with quantitative studies as it seeks knowledge by determination, generating and testing of theories. Postpositivist believes that a single reality exists but cannot be known in its entirety (Donaldson et al. 2017), therefore do not reject qualitative methods as an approach to research and acknowledge that the researcher's knowledge and experience influence the research process (Creswell and Plano Clark 2017).

In contrast, the **constructivist** worldview is associated with the thinking that multiple realities exist, depending on the experience of an individual, and do therefore apply qualitative research methods that allow the investigators to understand the meaning of phenomena through multiple participants' views (Creswell and Poth 2017). **Transformative worldviews** are linked with the need for social justice and human rights. The transformative approach is commonly used in human rights, social justice and political research that aims to improve and change the social world for the individuals in need (Creswell and Poth 2017; Donaldson et al. 2017). Finally, the **pragmatist worldview** is adopted by the majority of mixed methods researchers (Creswell and Plano Clark 2017). Other scholars such as Joshi (2013) would call it the mixed methods paradigms, which can be applied for mixed methods studies. This worldview is problem-oriented and focuses on the research questions rather than the methods and the idea of allowing multiple views of reality. It allows the researchers to use multiple data collection methods to answer their research questions, as its problem-oriented, which combines qualitative and quantitative methods of inquiry (Joshi S 2013; Shannon-Baker 2016; Creswell and Plano Clark 2017). These worldviews are different in terms of their views on ontology, epistemology, axiology, methodology, and rhetoric. See Table 28 Elements of worldviews and implications for practice, adapted from (Creswell and Plano Clark 2017).

Table 28 Elements of worldviews and implications for practice, adapted from (Creswell and Plano Clark 2017)

Philosophical Question	Postpositivist	Constructivism	Transformative	Pragmatism
Ontology (What is the nature of reality?)	Singular reality (e.g., researchers reject or fail to reject hypotheses)	Multiple realities (e.g., researchers provide quotes to illustrate different perspectives)	Multifaceted and based on different social and cultural positions (e.g., researchers recognise different	Singular and multiple realities (e.g., researchers test hypotheses and provide

			power positionalities in our society)	multiple perspectives)
Epistemology (What is the relationship between the researcher and that being researched?)	Distance and Impartiality (e.g., researchers objectively collect data on instruments)	Closeness and subjectivity (e.g., researchers visit with participants at their everyday field to collect data)	Collaboration (e.g., researchers actively involve participants as collaborators, build trust, and honour participant standpoints)	Practicality (e.g., researcher collect data by "what works" to address research question)
Axiology (What is the role of values?)	Unbiased (e.g., researchers use checks to eliminate bias)	Biased (e.g., researchers actively talk about and use their personal biases and interpretations)	Based on human rights and social justice for all (e.g., researchers begin with and advocate for this premise)	Multiple stances (e.g., researchers include both biased and unbiased perspectives)
Methodology (What is the process of research?)	Deductive (e.g., researchers test a prior theory)	Inductive (e.g., researchers start with participants' views and build "up" to patterns, theories, and interpretations)	Participatory (e.g., researchers involve participants in all stages of the research and engage in cyclical reviews of results)	Combining (e.g., researchers collect both quantitative and qualitative data and mix them)
Rhetoric (What is the language of research?)	Formal style (e.g., researchers use agreed-upon definitions of variables)	Informal style (e.g., researchers write in a literary, informal style)	Advocacy, activist-oriented (e.g., researchers use language that will help bring about change and advocate for human rights and social justice)	Formal or informal (e.g., researchers may employ both formal and informal styles of writing)

9.2.1. Worldviews in the current research:

Since research must have a framework or philosophy that is based on the aims and objectives of the research, which will guide the research design, the aims of this study can be achieved by carrying out quantitative and qualitative studies; hence, **a pragmatism worldview** is the most appropriate philosophical assumption to follow. Although the study can adapt postpositivist worldview in the quantitative phase and constructivist in the qualitative phase, the advantage of the pragmatism in adapting both worldviews into one was believed to be more appropriate for this study since it can produce similar aims.

The nature of reality (ontology) in the quantitative phase has a singular reality compared to the qualitative phase that is based on the view of multiple realities that may provide a more in-depth understanding of the research objectives. To illustrate, the barriers to PA and attitude, experience, and healthcare management for knee OA may be influenced by individual characteristics and personal experience, which may differ from one participant to another; hence, multiple realities may exist. From an epistemological view, the qualitative phase was in the form of subjective interviews linked to the individual experience, as the researcher has more influence on the data through the choice of participants and method of data analysis. On the other hand, quantitative phase objectives on measuring PF and PA were used as the researcher was more distanced from the data as objective tools were used. The values of bias in the postpositivist and constructivist views are different; in the postpositivist worldview, data can be tested for bias, while in the constructivist worldview; the researcher uses reflexivity to make sure their influence on the data is clear (Creswell and Poth 2017). However, pragmatism would offer both methods for collecting and analysing data, which offer the flexibility and plurality of research design to achieve the aims of this research project. Since it is problem-oriented, the researcher can adapt the most appropriate methods to seek answers for their research questions (Shannon-Baker 2016; Donaldson et al. 2017). Therefore, in this study, phase one results were needed to be explained and adapting an emergent mixed method was believed to address the research questions in the second phase.

9.3. Sample

Purposive sampling was used to recruit a sample of 26 participants from groups identified from phase 1 results, such as physicians, physiotherapists, people with knee OA, non-arthritic healthy members of society without knee pain. In addition to participants identified after initial interview analysis of phase 2 were recruited using a thematic sampling strategy and included personal trainers and teachers. Moreover, the study aimed to interview policymakers from MOH and the Saudi Sports Federation; but, due to the inability to reach potential participants from these organisations, they were not included. Hence, it was not possible to investigate the current strategies to promote PA or the healthcare organisation to manage knee OA from the policymakers' perspective.

The reason for choosing purposive sampling is that the chosen diverse sample may be able to provide a detailed exploration of the research questions due to their experience and their clinical characteristics to explain the results of phase 1 (Bryman 2012). This type of sampling would exhibit a range of attributes, behaviours, experiences, and different situations; and achieve a greater depth of understanding and insights into the barriers to PA in people with knee OA and physiotherapists barriers and attitudes towards clinical practice guidelines in Saudi Arabia (Creswell and Plano Clark 2017). Sample size in qualitative research should be small due to the richness, complexity of data, and the difficulties associated with managing a large sample size (Ritchie et al. 2014). Consequently, qualitative research aims to attain saturation (Fusch and Ness 2015), in which increasing the sample size would not add new information.

Saturation occurs during analysis when rich themes are created, and no new data can emerge (Fusch and Ness 2015). Although 'no size fits all', Baker and Edwards (2012) suggest that a sample size of 12 is sufficient to reach saturation, while Adler and Adler (2011) advised graduate students to sample between 12 and 60. In addition, Ritchie et al. (2014) proposed several determinants of the sample size, of which the inclusion of multiple participants categories/ groups within one study may lead to larger overall sample size. The initial aim was to recruit participants with knee OA, non-arthritic healthy individuals (without knee OA), physiotherapists and physicians, as they were believed to provide richer perspective in relation to the research questions.

9.3.1.1. Participant category: Practitioners and professionals

9.3.1.1.1. Physiotherapists

Physiotherapists are an essential profession in healthcare management for knee OA; they are the providers of most conservative interventions. Physiotherapists are the healthcare speciality that is arguably most concerned with exercise and PA, which may in turn significantly influence the communities' PA and promote PA in knee OA individuals. However, in phase one results, knee OA participants responded that physiotherapists do not affect their decision to exercise. Hence, it was essential to include physiotherapists to understand their attitude and barriers towards the implementation of clinical practice guidelines and PA promotion.

Eligible physiotherapists must hold a minimum of a bachelor's degree in physiotherapy and be licensed to work as physiotherapy specialist under the Saudi Commission for Health Specialties, with a minimum of two years' experience in treating musculoskeletal disorders. The researcher believed that a minimum experience in dealing with knee OA would help the participant understand the interview questions related to the guidelines and the barriers to PA.

9.3.1.1.2. Physicians

In Saudi Arabia, physicians are usually the gatekeepers for managing knee OA and the first line of seeking medical intervention. However, in the results of the first phase, knee OA participants maintained that physicians advice did not affect their decision to participate in PA or exercise. Therefore, there was a need to involve physicians in the second phase of this study in order to understand their perspective on opportunities and barriers to PA in individuals with knee OA.

Three specialities were included: Orthopedic surgeons, Physical medicine and Family physicians, all of which are involved in managing knee OA. **Family physicians** (FP) in Saudi Arabia are the speciality that is working at primary healthcare centres, which are expected to be dealing with a variety of individuals from the community and could influence the PA level of the individuals. Family physicians complete a residency program after graduation, which qualifies them to treat and monitor the whole family throughout their life (Richards

2018; American Academy of Family Physicians 2020). The difference between FP and general physicians is that the FP receive specialised training in paediatrics, obstetrics and gynaecology, and geriatrics. This is in addition to several practical difference in terms of the type of treatment provided and the type of individuals (Richards 2018). **Orthopaedic surgeons** are those who specialized in the diagnosis and preoperative, operative, and postoperative treatment of diseases and injuries of the musculoskeletal system. **Physical rehabilitation** medicine, or also known as physiatry, is a speciality concerned with managing the patient's medical issues as they participate in the rehabilitation process. They are different from physical therapists as they make and manage medical diagnoses and prescribe the therapies that physical therapists will subsequently perform (American Academy of Physical Medicine and Rehabilitation 2019).

9.3.1.1.3. Physical activity professionals

Personal trainers and undergraduate school sports teachers were identified as important to PA during the first interviews with knee OA individuals, physicians and physiotherapists. A personal trainer was needed to explore the trend of medical treatment in gyms as well as their opinion on PA of the community and their role in the promotion of PA. On the other hand, an undergraduate school sports teacher was invited since there were several comments on the role of school education in promoting PA and the need to change school student's awareness towards PA. Hence, both professions were included in the interviews via thematic sampling strategy, as indicated by the first interview responses.

9.3.1.2. Participant category: Public

9.3.1.2.1. Non-arthritic Healthy adults

The inclusion of non-arthritic healthy adults was mainly to explore their awareness, facilitators and barriers towards PA, which can be compared to individuals with knee OA. Non-arthritic healthy adults aged ≥ 18 years old without any musculoskeletal complication were recruited.

9.3.1.2.2. Individuals with Knee OA

Individuals with knee OA were included as long as they have a physician's diagnosis of OA by either radiographic evidence or symptomatic assessment, and they must have previously received healthcare treatment at least in one clinic in Saudi Arabia. No limitation regarding the stage or grade of knee OA were included since it was felt this would not influence the findings as long as the barriers and facilitators to PA, individuals' experience with the disease, and the healthcare-seeking journey can be discussed.

9.3.1.3. Participant category: Civil society organisations

9.3.1.3.1. Saudi Physical Therapy Association

As the only organisation related to physical therapy practice in Saudi Arabia, the Physical Therapy Association have a role in the education of healthcare providers regarding physiotherapy practice in hospitals and the community in terms of physical activity promotion.

9.4. Recruitment and consent

Participant recruitment was achieved via social media posts (Facebook, Twitter and WhatsApp) and advertisements at ten local hospitals in the three main regions in Saudi Arabia (Western, Central and Eastern). Hospital advertisements were carried out by contacting clinicians, who agreed to circulate the poster and contact their colleagues about the research. Recruitment letters and posts were in the local Arabic language of the study population. Moreover, participants from phase one of the study who consented to be contacted for further studies if needed were contacted and were invited to participate in the second phase.

Recruitment was based on the snowballing, flow populations technique and thematic sampling strategy (Creswell and Poth 2017; Naderifar et al. 2017), in which the researcher approached particular locations and individuals who also suggested other participants. Later, the researcher ensured that the participants were diverse but limited to the groups' characteristics. Participants who wanted to participate contacted the researcher via WhatsApp messages or called the researcher directly to clarify the objectives of the research and their role in data collection and raise any concerns. Hence, several contacts were made from the advertisements to suggest potential participants who can be involved in the knee OA individuals' group. The researcher also spoke to potential participants who were eligible and discussed the study aims and impact. Those who were willing to participate received the participant information sheet of phase 2 and consent forms, which was discussed with them to clarify any concerns before participation. Finally, people who contacted the researcher had been given a week to consider participating in the research. If they accepted the invite, then the interview was arranged; if not, they were not contacted any further. The consent forms were sent back to the researcher electronically (i.e., the researcher sent the patient information sheet and consent form to eligible participants, then the participant could print the consent form and sign it, or sign it electronically, based on their preference. The printed and signed consent forms were scanned or photocopied and sent to the researcher electronically). In addition, for participants without technical knowledge, consent forms were sent and received through post/mail.

On the day of the interview, the information sheet was further discussed, and participants could ask questions and raise any concerns. Since the interview was carried out via telephone, the participants had the freedom to choose their preferred location and time as long as it was quiet and the sound was clear. The researcher had to adapt to the participants preferred time of the interview, which had to be done in appropriate locations (i.e., private room) to assure participants' privacy and the quality of interview records.

9.5. The interview

The qualitative design used the semi-structured interview to answer the research questions. The semi-structured interview is a qualitative research method that uses pre-determined open questions while allowing the researcher to explore further specific themes or responses (Edwards and Holland 2013). The interview questions were guided by the findings of phase 1 and the literature around knee OA management and the healthcare system in Saudi Arabia (Jette et al. 2003; C. et al. 2005; Jamtvedt et al. 2008; Bennell et al. 2014; Ramírez-Vélez et al. 2015; Al-Jazairi and Alharbi 2017; Piercy et al. 2018; Rausch Osthoff et al. 2018) and from physical activity studies (Schutzer and Graves 2004; Al-Hazzaa et al. 2012; Stevenson and Roach 2012; Kanavaki et al. 2016; Kanavaki et al. 2017; Qin et al. 2017; Al-hazzaa 2018). The interview schedule had several routes, an opening, transitional, core and closure questions (Bell 2013; Galletta 2013; Ritchie et al. 2014). An interview schedule guided the interviews; however, they were minimally adjusted for each participant group (e.g. terminology was adjusted to be more relevant for the participant group)(Appendix K).

9.5.1. Semi-structured interviews as a method:

The literature is controversial when it comes to the types of qualitative interviews, as the term interview is thought to be broad (Bryman 2012). The majority of authors have proposed three main types of qualitative research interviews: structured, semi-structured, and unstructured interviews (Edwards and Holland 2013). First, structured interviews have been employed mostly as survey research (Edwards and Holland 2013). This type of interview aims to ensure that all the interviews have the same question order and specific answers for each question (Edwards and Holland 2013). It is subjected to the statistical analysis of a large number of respondents. The other types of qualitative interviews have more flexibility and are less structured compared to the previous method. For instance, the semi-structured interview is considered a reasonably flexible method with ideas to discuss but accepts the emergence of new questions as the interview progresses (Galletta 2013). One of the features of this type of interview is that it can include open-ended questions as well as theoretically-driven ones, which allow for exploring the experience of participants and discussing pre-defined ideas (Galletta 2013). Furthermore, the use of probes as additional questions provides further opportunities to search for novel, relevant information (UK data service 2019). Lastly, the unstructured interview, which aims to gather information and build themes and theories based on a natural conversation between the interviewer and interviewee (Edwards and Holland 2013). The key feature of this type of interview is flexibility in the form of adjusting the interview based on the conversation and issues that emerged. This would help to develop themes, theories and emphasis of the research based on the interview itself. An example of such an interview is life history, which starts mainly with a single question and prompts more details and exposure (Edwards and Holland 2013).

Semi-structured and unstructured interviews are both commonly used approaches in qualitative research. The differences between the approaches are the amount of flexibility, the theoretical stance and perspective of the purpose of the research (Edwards and Holland 2013; Galletta 2013). This research is adapting a semi-structured interview method, as it has the flexibility and the ability to discuss topics and issues of concern without preventing the emergence of new ideas or theories, which would enhance the understanding of the results of phase 1. There are many advantages in using such a method for data collection in this study's second phase. According to Ritchie et al. (2014), it would provide insights and discover information that was not accessible by other techniques because of the flexibility and structure of interviews. It is merely a normal conversation, but it has objectives and standards (Alshenqeeti 2014). For instance, the interview questions can be explained and adjusted to ensure the interviewee's understanding.

Additionally, when recorded, interviews would offer an opportunity to carefully listen and repeat the interview, which would increase the accuracy of the transcripts and reports (Bell 2013). It is also acknowledged that interviews, compared to other methods, are an economical and low-cost method of research (Alshenqeeti 2014). Although qualitative researchers commonly use interviews, critiques on the interview as a research method have been raised. Alshenqeeti (2014), in his critical review of interviews as a research method, stated that one of the drawbacks could be the interviewee's willingness to be exposed and share their personal life with the researcher. Furthermore, several scholars have previously argued that interviewee responses are subjective, and they may change over time, which could be distinct from reality (Hermanowicz J. C 2002; Hammersley 2011; Holstein and Gubrium 2011). Another critique of the interview is the time consumption, which could be due to the steps of building the protocol, interviewing, preparation for analysis via transcribing, coding and may be a translation (Alshenqeeti 2014; Ritchie et al. 2014; Taylor et al. 2016). Nevertheless, Ritchie et al. (2014) view these critiques as exaggerated and that they ignore the potential benefits of novel qualitative findings' through the use of interviews.

9.5.2. Telephone interview

The interview can take many forms, such as; face-to-face, internet communications and telephone interviews (Opdenakker 2006; Ritchie et al. 2014). Although face-to-face interviews are the most common form or technique, the number of studies using the alternatives is rising (Drabble et al. 2016). Each of these forms has its advantages, disadvantages, and rationale for use. Johnson et al. (2019) compared the different approaches to qualitative interviews in terms of time, place and technology. The author claimed that only face-to-face interviews could obtain social cues such as body language, voice and other cues, which may provide the interviewer with additional information. Those social cues are essential in research that is interested in the subject's attitudes, impressions and personal experiences (Drabble et al. 2016). However, it is argued that these social cues might direct the interview beyond the research objectives (Opdenakker 2006). It may also lead to a biased interpretation of the interviewee responses (Sturges and Hanrahan 2004; Novick 2008).

The advantage of 'being there' in time and place in the face-to-face interview would allow the interview to be conducted in a more natural better environment (Opdenakker 2006; Drabble et al. 2016; Johnson et al. 2019). However, this could also be a disadvantage due to time and costs, which may sometimes include travel that is costly and time-consuming (Drabble et al. 2016). Conversely, the telephone interview has the advantage of broad geographical access, lower costs than travelling and the ability to reach a large geographical distribution (Johnson et al. 2019). Also, while the face-to-face interview has the advantage of obtaining social cues, this may limit the ability to discuss sensitive topics; participants may be more comfortable with telephone interviews as anonymity is achievable. Telephone interviews have been argued to have certain disadvantages, such as the ability to control the interview environment, obtaining sufficient social cues, shorter interview duration or less depth and richness of data (Irvine 2011; Irvine et al. 2013). Compared to face-to-face interviews, other scholars found that telephone interviews have similar depth, length, and type of response, with better interview dynamics (Sweet 2002; Sturges and Hanrahan 2004; Vogl 2013).

9.5.2.1. Telephone interview as a method

Acknowledging the small number of differences between face-to-face and telephone interviews, the choice of carrying out a telephone interview was based on the resources, time and objectives of this study. Moreover, the study was carried out as part of a PhD thesis based in the UK, while the study population were geographically located in different regions in Saudi Arabia. Therefore, considering the advantages of telephone interviews in terms of the geographical area coverage, travel costs and timescale, and the limited differences between the two form of interviews, the telephone was considered to be the preferential approach.

The telephone interviews were carried out by a secure call recorder app, which allows the interview to be automatically recorded and saved on private cloud storage with two-factor authentications (Farooq and de Villiers 2017). The telephone interviews lasted approximately 20-45 minutes and started by introducing the research, researcher and interview topics. The participants' demographics and characteristics were collected at the beginning of the telephone interview, which was recorded on a pre-designed form that can be seen in Appendix L.

9.6. Pilot interview

The researcher conducted a pilot interview with one Arabic speaker at Cardiff University to practice the interview techniques and test the questions' quality and clarity. This led to the development of the researcher's understanding of the interview techniques. Moreover, the recorded data from the pilot interview was not used for analysis, and the person who was interviewed was not invited to the actual data collection.

9.7. Data management

The interviews were digitally audio-recorded and securely uploaded to the Cardiff University server. In addition, a copy was made in a storage drive that was kept in the researcher’s locked filing cabinet at Cardiff University, School of Healthcare Sciences. The primary researcher transcribed verbatim the recorded Arabic interview after data collection of 12 interviews as the minimum sample size, then ensured transcripts' accuracy by listening to the record again. This would avoid misinterpretation of content and increase the transcripts' accuracy (Ritchie et al. 2014; Al-Amer et al. 2016). The anonymity of participants was established throughout the transcription and the analysis by removing potential participants identifiers.

9.8. Translation

The primary researcher translated the Arabic transcripts into English; to analyse the data and make it understandable to the audience of the PhD research. The translation of interviews was conducted initially by the primary researcher who conducted the interviews; to contextualise the conversation, as he was a native Arabic speaker and qualified English writer. The primary researcher had a master’s degree from the UK, and

IELTS exam score of seven, and was a PhD candidate at Cardiff University, UK. Hence, the primary researcher is experienced with English translation and writing (Appendix M). Furthermore, a native Arabic PhD student, external to the project, who also has experience with English writing and holds an English language certificate, blindly translated three interviews (out of 26) to assess the two translators' level of agreement. Later, a meeting was conducted to assess the translations' agreement; if both agreed on the terms used, then the primary researcher would continue to translate with the same style. However, where there was disagreement between translators, a third external translator who is also a native Arabic PhD student with English language qualification was involved in making the final decision regarding which terms were to be used. This checking procedure led to several changes to the translations being undertaken, and further consideration was subsequently given to the terms that were adopted in the other transcripts. The literature shows that including an independent reviewer in the translation would increase the credibility and confirmability of the findings, enhancing the research rigour (Squires 2008; Squires 2009).

9.8.1. Justification for translation

The Arabic language has two forms; spoken and classical Arabic; the spoken or "alammeya" has many different versions based on the geographical (urban, village, and Bedouin) and social status compared to the written or literary Arabic (Abu-Rabia 2000; Rubio 2008; Versteegh 2014). It is well known in the literature that the Arabic language is complex and different meanings can be captured by the same word, and native speakers understand the meaning of sentences by capturing their context (Al-Amer et al. 2016).

A third-party translator was not appropriate to include due to the complexity of the spoken Arabic language in the data collection region; hence other Arabic speakers may not understand. To elaborate, the spoken Arabic language has a different meaning if captured out of context, while some terms may not be understood by someone who is not from the same area with the same background. Van Nes et al. (2010) further highlight that professional or third-party translation may cause loss of the intended meaning of the interview. Moreover, cross-language research studies have stated that the limitations of external translators could affect the meaning of the data by reducing the content and producing information that is not the researcher's goals (Aranguri et al. 2006; Berman and

Tyyskä 2011). Moreover, the interview transcripts' back-translation was not carried out because it would not obtain the exact meaning of the interview since the back-translation will translate English to written Arabic that is different from the spoken one (Squires 2009).

Furthermore, as the interpretation or delivery of meanings in qualitative research is essential, the language difference in back-translation may affect the meanings of the data (Squires 2009). In order to preserve the meanings of specific phrases, metaphors that are language-specific are kept in Arabic but explained in English between brackets (van Nes et al. 2010; Al-Amer et al. 2016). It is acknowledged that the challenges of language translation may involve interpretation to deliver the exact meaning of the interview (van Nes et al. 2010), which was approached with caution with minimal interpretation to deliver the exact meaning of the interviews.

According to Polkinghorne (2007), the trustworthiness of qualitative research is high when the meanings of the interviewee responses are not distant from the interpretation in the findings, which means that the main idea of conducting quantitative research interviews is to reflect the participant's opinion by his/her own words. The inadequate translation may change the resultant themes and may not reflect the actual participants' responses, which could affect the credibility and dependability of the cross-language research (Squires 2009). Therefore, to maintain the integrity of the qualitative data, the best choice of translation was to be carried out mainly by the primary researcher since they can understand the context of data and deliver the exact, intended meanings of the interview while the translation was approached with caution. Moreover, translations were verified by second and third translators to ensure the accuracy of meanings were achieved.

9.9. The trustworthiness of research:

Compared to the validity and reliability in quantitative research, trustworthiness reflects the quality, validity and rigour of qualitative research. It is composed of four items; Credibility, Transferability, Confirmability and Dependability (Bell 2013). **Credibility** indicates confidence and truthfulness and assesses the accuracy of findings, which can be evaluated with triangulation that aims to ensure that research findings are robust, vibrant, comprehensive, and well-developed. Noble and Heale (2019) identified two purposes for triangulation; 1) confirmation or convergent validation, which aims to improve the accuracy with which findings are demonstrated; and 2) completeness or holism, which aims to increase the scope of the findings. There are five triangulation types (Bell 2013); data, investigator, theory, methodological and environmental. To ensure this research was credible, multiple types of triangulation have been utilized. Investigator triangulation was carried out by involving three additional investigators (thesis supervisors) experienced in qualitative research in analysing the interview transcripts. Moreover, environmental triangulation may have been achieved by selecting participants from different regions in Saudi Arabia.

Transferability is how the findings apply to other contexts with similar situations, populations and phenomena (Leung 2015; Cypress 2017). This can be achieved by providing a detailed description of the research methodology and findings, which allows other researchers to consider using the same methods as part of their own research. A full and detailed description of the methodology can be seen in this chapter (research design) and the qualitative phase chapter in the current study.

Confirmability is the neutrality of findings that means the researcher does not bias the findings; instead, it is based on participants' responses (Cypress 2017). It requires ensuring that data analysis and interpretation is not affected or guided by the researcher interest (Connelly 2016). To achieve confirmability, a trail of every step in the analysis process must be written. In this research, the methodology chapter explained in detail every step in the analysis process. Thus, the transparency of the analysis and the involvement of multiple investigators and the inductive approach that has been used are all aimed to avoid bias or personal motivation (Connelly 2016). The analysis of interview transcripts aimed to find patterns in the data for emerging themes.

Dependability is the ability to repeat the research by other researchers while the findings would be consistent (Elo et al. 2014; Cypress 2017). This can be achieved by consulting an expert who is not involved in the research to review and examine the research process and the data analysis in order to ensure that the findings are consistent and may be repeated (Bell 2013; Noble and Heale 2019). This research's dependability was achieved by consulting professionals who are experienced with qualitative research and a team of supervisors, and several annual reviews conducted by Cardiff University, School of Healthcare Studies.

9.10. Data analysis

9.10.1. Analysis software

Data were managed using NVivo qualitative data analysis software (QSR International Pty Ltd. Version 13, 2019), which is not an analysis software but rather a tool to organise the data, and the researcher is always in control (Zamawe 2015). The advantages of NVivo software include character-based coding, precious text capabilities and multimedia functions (Zamawe 2015). Moreover, the strength of NVivo lies in its high compatibility to research designs. The software works with a wide range of qualitative research designs and data analysis methods, such as mixed methods, while it saves time and increases analysis accuracy (Zamawe 2015).

9.10.2. Thematic analysis

Qualitative analysis has two main approaches, namely, descriptive and interpretative (Sandelowski and Barroso 2003). Descriptive approaches aim to describe the findings rather than proposing interpretation, which can be achieved with descriptive phenomenology, content analysis and thematic analysis (Sandelowski and Barroso 2003). Although most of the qualitative analysis relies on creating codes and themes to make sense of data, they are different in their philosophical background, approaches to analysis, and transparency (Williamson et al. 2018). Thematic and content analysis is the most commonly used approach for analysing qualitative data; they are regularly used interchangeably and occasionally with confusion (Sandelowski and Leeman 2012; Vaismoradi et al. 2013).

Thematic analysis is a foundational, independent descriptive approach for qualitative analysis, which is defined as a method for identifying, analysing and reporting patterns within data (Braun and Clarke 2014). It is a method or technique rather than a methodology or theoretical framework such as in other types of analysis (e.g. narrative, grounded theory and phenomenology) (Given 2012). Thematic analysis is considered an umbrella term for a range of different approaches and is commonly used within qualitative research (Clarke and Braun 2014). Similarly, content analysis is an approach to systematically code and categorise texts unobtrusively in order to search for patterns, frequency, relationships and structure of communication (Vaismoradi et al. 2013). Both analytical approaches have similar definitions and aims; however, the content analysis would allow for qualitative documents to be analysed with a quantitative approach by describing word counts and frequency of certain terms to find relationships between the meaning of words (Elo and Kyngäs 2008). In contrast, the thematic analysis would provide a detailed description of qualitative findings and look for patterns in the data, which provides depth to meaning from the data (Braun and Clarke 2006).

Content analysis relies on the frequency of codes to find meaning, which may lead to a risk of missing data and removing the meaning of texts (Elo et al. 2014). At the analysis stage, the thematic analysis approach advises the use of both latent and manifest content in data analysis, compared to content analysis that allows for a choice between latent or manifest content (Vaismoradi et al. 2013). In addition, the thematic approach has six steps of analysis compared to three in the content approach, which may provide a more robust and transparent analysis process (Vaismoradi et al. 2013). Overall, both approaches are very similar with minor differences; thus, thematic analysis was chosen as the approach to analyse the qualitative data of phase 2 to look for meaning for the results of phase 1 and were described in the following section.

First, according to Braun and Clarke (2006), thematic analysis does not rely on one theoretical framework; instead, it can be used with various frameworks, which makes it a more accessible approach. Moreover, a thematic analysis will rely on the qualitative texts to report a description of themes that have not yet been explored without the risk of losing meaning, such in content analysis (Elo et al. 2014). The transparent steps of thematic analysis allow the process to be explicit, replicable and trustworthy. Additionally, thematic analysis would allow the emergence of themes from latent and manifest content while also allow for examining the similarities and differences in the responses (Braun and Clarke 2006). Thus, it would propose a more in-depth picture of the studied experiences and an appropriate approach to answer the research questions while allowing for the exploration of emergent phenomena. Also, the non-linear process of thematic analysis allows for revision of the analysis process as the more transcripts are analysed, the deeper the researcher's understanding will become. The non-linear process also allows the researcher to revise the generated categories and themes to ensure that they are representative of the data set and their importance to the findings. Lastly, thematic analysis allows for the use of the inductive and deductive approach in finding relevant codes through the explanation of pre-determined study objectives (deductive) and the emergence of new findings (inductive) (Clarke and Braun 2014).

9.10.2.1. Thematic analysis steps

Braun and Clarke (2006) introduced six steps of thematic data analysis that are flexible to the data and research question. These steps were followed in the current study in order to analyse the interview transcript and produce a discussion of the final themes that could answer the research questions. Before describing the steps, several terms must be defined; first, '**code'**, which is a word or short phrase that is labelled to capture a feature of the data that is interesting to the analyst (Saldaña 2016). **An analytical memo** is a term used for the researchers' personal notes and reflections on the data collection and analysis, which may include interpretations of interview responses (Schwandt 2011). Moreover, the **category** is defined as the process of grouping related codes of similar interest in one group (Schwandt 2011). The thematic analysis's final product are the themes that may include several categories, which, as defined by Braun and Clarke (2006), is a pattern of similarity in the participants' responses that can be raised to generate themes. Figure 9 is a diagram to explain the thematic analysis steps for the qualitative phase.

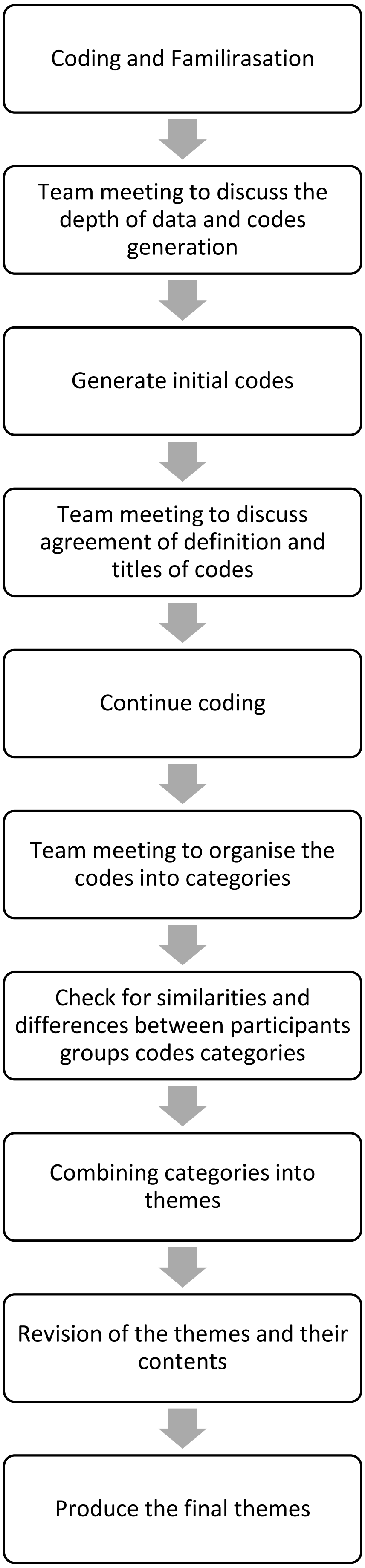

Figure 9 Diagram of the thematic analysis steps in the qualitative phase

Following Braun and Clarke’s (2006) guidance on thematic analysis, the first step was to become **familiar with the data**, which was achieved by transcribing the interview first, then reviewing the transcriptions and audio records, as well as translating and reviewing the translations while keeping reflexive notes in the form of memos. Initially, the researcher practiced coding of several interviews to become familiarised with both the data and the NVivo qualitative data storage software. Those initial codes were reworked and developed for the final analysis (Nowell et al. 2017). During the first step of the analysis, data were discussed by the research team to ensure agreement and that ideas can emerge from the interviews.

The following step was to **generate initial codes**. According to Braun and Clarke (2006), the process of generating initial codes is started during the reading of the transcripts and forming initial ideas of the codes that refer to the basic element of raw data. Coding was managed using the NVivo software by tagging and selecting texts from all the interview transcripts, line by line (Saldaña 2016). There are two types of coding approaches; inductive or open coding and deductive or theoretical coding (Blair 2015). In inductive coding, codes are emerged from within the texts and theory is developed from the data rather than forced upon it, whereas in deductive coding, the researcher creates the codes before analysis based on the literature and theories (Blair 2015). Consequently, inductive approaches are used to develop theories of under-investigated areas and to make a generalisation from specific observations, while the deductive approach tests the available theories (Elliott 2018). According to Creswell and Poth (2017), deductive coding limits the analysis with a pre-determined code rather than reflecting the participants' views in a traditional qualitative way. Inductive coding was used instead of deductive (theoretical) because phase 2 aimed to explain the results of phase 1, and there is limited research exploring PA of knee OA individuals in Saudi Arabia. Therefore, no prior theories needed to be tested; instead, it was more beneficial if the data reflects the codes and themes, and theories are allowed to emerge. However, Braun and Clarke (2006) maintained that prior knowledge of the research topic could inform the researcher's theoretical insights, which in turn could influence the generated codes into theoretical ones.

At the generation of the code, approximately a hundred codes were generated from the transcripts of the 26 interviews. A memo was also created to keep the reflection of each code's ideas and the context behind it. The initial codes were reviewed and discussed with the project supervisors, who also coded several interviews separately to compare and assess the agreement on the initial codes. A list of all codes was discussed for agreement with the further three researchers (supervisor). Then, when agreement on the codes and their definitions had been achieved, the primary researcher continued to code the rest of the interviews. If there was no agreement, the primary researcher would decide on the most appropriate codes and interview extracts that reflect the transcript's meaning. However, since this is an ongoing process, the codes were modified and adjusted while new codes were created and reviewed again (Nowell et al. 2017)

The next step of the thematic analysis was to **search for themes**. The themes are characterised by their applicability and relevance to the research question or the importance of the theme's findings (Nowell et al. 2017; Castleberry and Nolen 2018). However, the emergence of themes is not a straightforward approach with specific rules; instead, it is a flexible approach that relies on the researcher’s judgment (Braun and Clarke 2006; Clarke and Braun 2014; Nowell et al. 2017) In order to search for themes, the large number of codes had to be reduced and organised, which was achieved by an organisation of codes into categories by combining the similar codes that share the same interest. This step was carried out by all the research team members (the primary researcher and three supervisors), using sticky notes of all the codes. Several codes were collated together to create a category (or categories) (

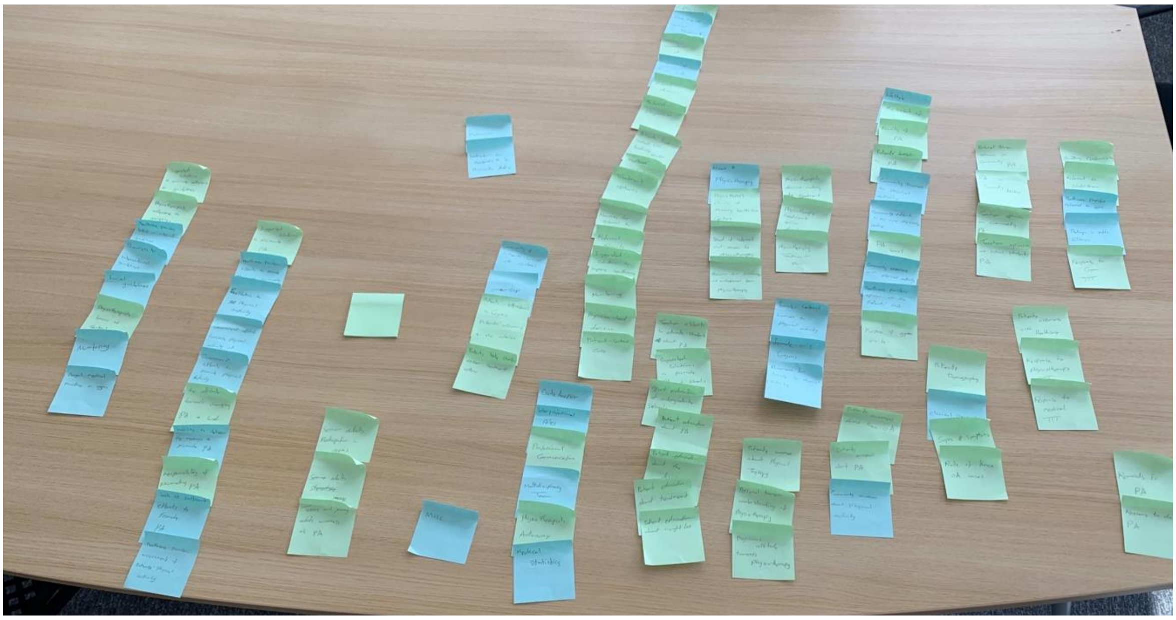

Figure 10,

Figure 11).

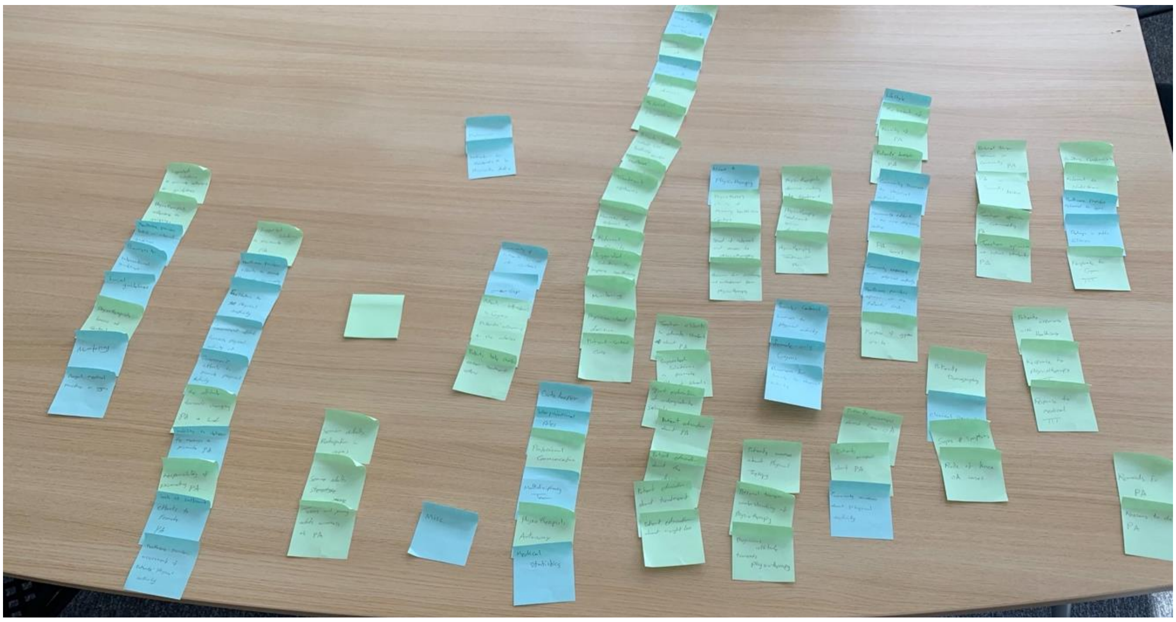

Figure 10 step three of thematic analysis, listing all codes on walls to create categories

Figure 11 step three of thematic analysis, the initial categories

This was a flexible process that involved discussions, revision of the meanings and context of the codes and a revision of the codes and categories. Sorting codes into categories was carried out for all the participant groups together. In order to assess the difference in the categories that could be created based on the findings of each group of participants, a separate step of category listing by each group was carried out.

Each category was then reviewed and adjusted with their codes to assess if the category reflected the codes within. Once organising codes into categories, the categories were reviewed by the primary and three additional researchers. The next step was to list all the possible categories from each group (Appendix S) and check the similarity of those categories; therefore, a table was created to compare the categories of each group (Appendix T). Afterwards, the primary researcher proposed choices of themes based on the relevance of each category or findings to the research questions. For example, the 'gender difference' category emerged in all participants groups, but after discussion with the research team, it was believed that it could be collated with other categories rather than making it a theme in its own right. On the other hand, evidence-based practice and physiotherapy service were not prevalent among all the participant groups, but they have keyness as they were highly relevant to the research question. Since a theme is defined as a pattern, essential data or something interesting that combines several categories (Bell 2013), therefore, the previously identified categories were combined into the following initial themes, based on their shared interest or topics (see Appendix U: Initial themes, categories and codes).

The fourth step of thematic analysis is to **review the themes,** in which an assessment of the quality and content of the initial theme must be carried (Clarke and Braun 2014). In this study, the previous initial themes are checked for their content and their reflection of the data set. Moreover, the themes and their categories are reviewed in order to consider if they can be combined into one theme or if a theme needs to be separated into two. Braun and Clarke (2006) describe two levels of reviews; first, at the level of the coded texts, this level aims to assess the data extracts' appropriateness within the theme. This step was achieved by reading the coded texts in each theme and assessing whether the data supported the theme sufficiently by sharing the same interest or they were too diverse to create a theme. For instance, the coded data within the 'control over life' theme was limited; therefore, it was combined with the 'Diverse Management of Knee OA' theme, which includes a category that describes knee OA individuals. Another example is the codes related to the response to treatments, 'the attitude to physiotherapy ', the limitations of the healthcare system and participants experience with the healthcare system codes, which were collapsed into one new theme 'Participants views of the healthcare system for individuals with knee OA'.

Moreover, several coded texts were reviewed for their applicability and quality, as they were moved between the codes that most closely reflected the correct meaning of the data. Later, the second review of the themes was carried out, which is the assessment of the themes when considering the entire data set (Nowell et al. 2017). Hence, themes were checked for their relationship with others, as they should be coherent yet distinct from each other (Nowell et al. 2017). At this level of reviewing themes, it was found that the 'Lack of Education and Awareness' theme did not fit with the other themes; so instead, it was separated as categories and combined with other themes. At the end of the fourth step of thematic analysis, four main themes emerged as coherent and which worked well together with their categories and coded extracts.

The next step in the analysis was **naming the themes**, which aims to describe the essence of each theme while also describing the story behind the theme (Braun and Clarke 2006). This process involved reading the extracts and analysing them in relation to the research question. In this study, the primary researcher read the themes and their extracts, which led to the following changes. Firstly, the theme ‘Diverse Management of Knee OA’ was found to be misleading and does not capture the essence of the theme. Hence, it was changed to ‘Organization of care of individuals with knee OA’, which describes the patient journey and their characteristics, the availability and organization of the multidisciplinary team.

Another example is the theme ‘Evidence-Based Practice in Physiotherapy’, which has been further developed into ‘Physiotherapy service and International guidelines practice for knee OA’ that describes the issues in the services and management of knee OA as well as the guidelines practice. At this stage, a new code was created, ‘Physicians adherence to the international guidelines’, which was developed to represent the participants' views more appropriately. The codes and categories in each theme were organized to provide a coherent story. A full description of each theme is provided in the findings (Chapter 10). The following is a diagram of the final themes and their categories (Figure 12). The final step in the analysis is **producing the report**, which is presented in phase 2 findings.

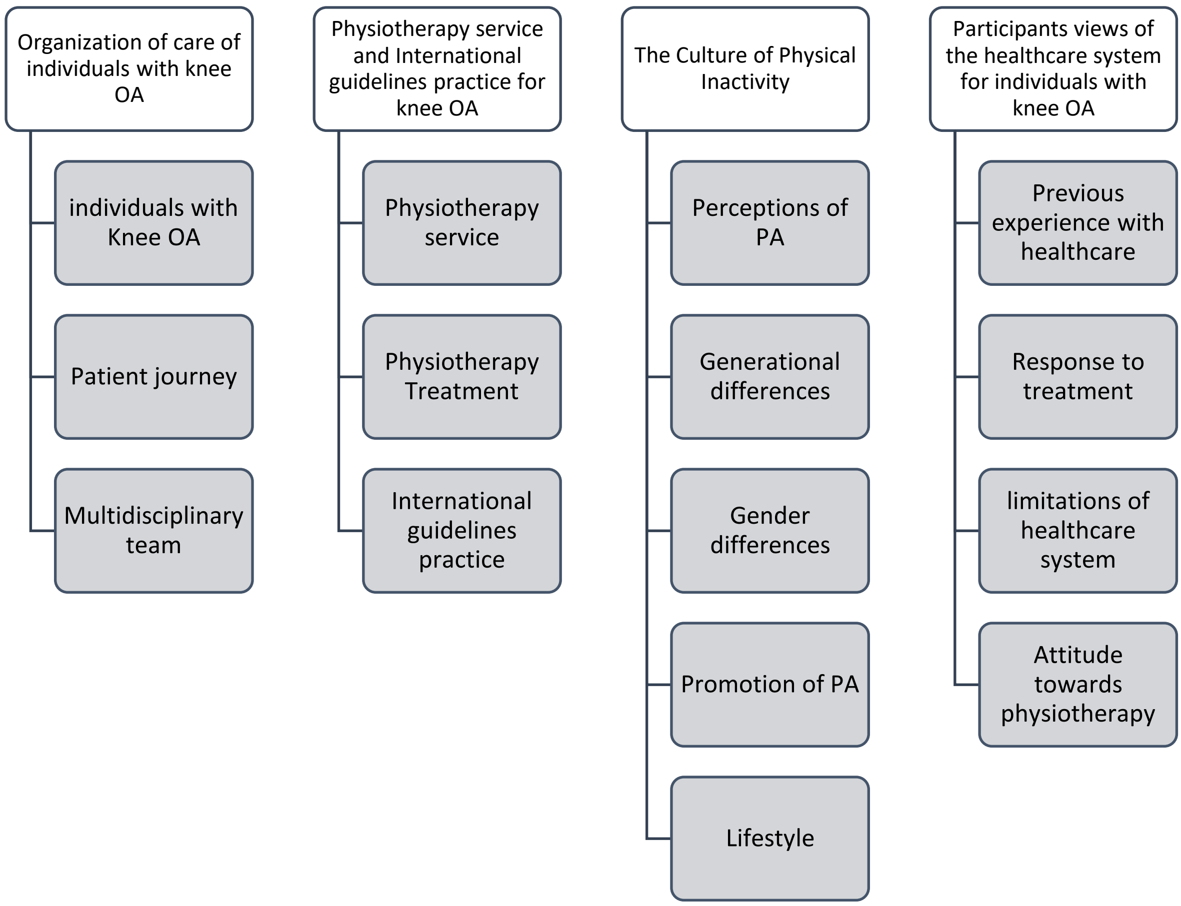

Figure 12 Final themes and categories

9.11. Ethical Consideration

Approval for phase 2 was granted by the School of Healthcare Sciences Research Ethics Committee on 20 June 2018, after submitting an application for a substantial amendment to the original study research protocol (phase1) (Appendix N). Participants received the patient information sheet and consent form a minimum of 24 hours (and up to a week) before participation, which informed them about the nature and procedure of the research. All data were non-identifiable using the participant's anonymised research code, not their name nor hospital number. Participants were allowed to withdraw anytime without affecting their medical care or legal rights. Withdrawn participant's data were destroyed immediately. Anonymity and confidentiality were maintained throughout the study, in which the participants' identification was not involved during data analysis nor in the results. Based on the participant's interest and request, a summary of the research results might be sent to the participants through e-mail, phone or post.

Investigation of healthcare management and barriers to PA was not received as a sensitive issue. However, healthcare providers may be influenced by the researcher since he is in a similar profession, which could lead to researcher bias. To elaborate, since the interview schedule had questions about the management of knee OA and the guidelines, and the researcher is a physiotherapist who has knowledge about this information, potential bias was noticed and approached with caution. Hence, the researcher carefully asked the questions that could indicate a bias towards the management guidelines and assured no personal opinion from the researcher would arise during the interviews. Moreover, this was cautiously avoided with several techniques, such as when the researcher was asking questions, no directions or impressions were applied during interviews. This may have led the participants to speak more freely, knowing there will not be any personal judgments on their responses. Finally, during the interviews with OA individuals and non-arthritic healthy individuals, there were privacy concerns raised from females regarding their responses as they described family and cultural barriers to PA. The researcher reassured the participants that their responses were confidential and no personal identification would be used in the results.

The researcher followed Cardiff University ethical procedures & the Data Protection Act 2018. Therefore, all data recorded electronically were securely stored in the Cardiff University server. All questionnaires that were collected using a paper version were stored in a locked cabinet, within a lockable cupboard in the researcher's office at Cardiff University. All processing and analysis of data took place at Cardiff University. The researcher ensured that all personal data were securely held to prevent any unauthorised access or accidental loss. The researcher ensured that all data was held securely throughout the process of reporting findings. Only the lead researcher had access to the data as appropriate for the analysis and dissemination. Research data would be stored for five years in line with Cardiff University research data retention policy. Patient-identifiable information such as contact details will be destroyed after one year after completion of PhD.

10. Chapter 10: Findings

10.1. Overview

Phase 2 aimed to explore the quantitative results of phase 1 related to the low level of PA in both knee OA and non-arthritic healthy comparator group, and barriers and facilitators to PA such as the lack of exercise classes in the area, past experience with exercise and personality. Therefore, the aim of phase 2 was to explore:

- Participants perspectives on the opportunities and barriers to physical activity in Saudi Arabia for individuals with knee osteoarthritis.
- Physiotherapists' barriers and attitude towards the guidelines in Saudi Arabia.

10.2. Participants

Semi-structured interviews were conducted with 26 participants (17 male and nine female) from different participants categories (Table 29): 5 non-arthritic healthy members of society without knee pain, eight individuals with knee OA, six physiotherapists (one of whom is a representative of Saudi Physical Therapy Association), five physicians, one personal trainer and one teacher. The participants were recruited from different Saudi Arabia regions, but the majority were from Makkah and Jeddah cities of the western region.

Table 29 participants demographics

Non-arthritic healthy group					
Participant number	Age	Gender	Level of education	Job	Location
18	52	Female	BSc	Housewife	Makkah
19	56	Male	Not Identified	Retired	Jeddah
22	22	Female	BSc	Student	Makkah
23	30	Female	MSc	Lecturer	Makkah
25	33	Male	BSc	Engineer	Riyadh
Physical activity professionals					

11	35	Male	BSc	Personal trainer	Makkah	
19	47	Male	BSc	Undergraduate school teacher	Makkah	
Knee OA group						
Participant number	Age	Gender	OA history	Level of education	Job	Location
13	56	Female	2 years, both knees	Not Identified	Housewife	Jeddah
14	54	Female	6 years, both knees	BSc	Housewife	Jeddah
15	58	Female	10 years, both knees	BSc	Housewife	Dammam
16	50	Female	7 years, both knees	Not Identified	Housewife	Jeddah
17	55	Male	10 years, both knees	BSc	Retired	Makkah
21	53	Male	1 year, both knees	BSc	Retired	Jeddah
24	65	Female	8 years, both knees	Not Identified	Housewife	Madinah
6	65	Male	7 years, both knees	BSc	Retired	Riyadh
Physicians						
Participant number	Age	Gender	Specialty	Experience	Location	
10	50	Male	rehabilitation medicine consultant	25 years	Makkah	
12	42	Male	Family medicine	15 years	Makkah	

26	40	Male	consultant orthopedic surgeon	25 years	Jeddah	
3	26	Female	Family medicine (R2)	2 years	Jeddah	
5	28	Male	Family medicine (R4)	5 years	Makkah	
			Physiotherapists			
Participant number	Age	Gender	Level of education	Specialty	Experience	Location
1	30	Male	BSc	orthopedic- Head of SPTA western region	7 years	Makkah
4	28	Male	MSc	orthopedic	2 years	Dammam
7	33	Male	BSc	orthopedic	10 years	Taief
8	27	Male	BSc	orthopedic	5 years	Makkah
9	35	Male	BSc	orthopedic	10 years	Madinah

10.3. Introduction to key themes

The thematic analysis led to the development of key themes and categories. The main themes developed were as follow:

- Organization of care of individuals with knee OA
- Physiotherapy service and International guidelines practice for knee OA
- The Culture of Physical Inactivity
- Participants views of the healthcare system for individuals with knee OA

A diagrammatic representation of the key themes and categories can be seen in Figure 12.

10.3.1. Theme 1: Organization of care for individuals with knee OA

This theme illustrates the perspective of people with knee OA and healthcare participants on the journey within the healthcare system in Saudi Arabia for the management of knee OA, from the time of the first contact with a healthcare professional to discharge. For individuals with knee OA, it describes the characteristics of knee OA, understanding of the disease and its management, ownership over their health and lifestyle, and their involvement in the healthcare journey. The findings also present the management options and decision-making process for the progression of care for individuals with knee OA. The theme also discusses the multidisciplinary healthcare team's availability and their professional relationship with other healthcare providers.

The theme is composed of three categories; **Individuals with Knee OA**, **Patient Journey**, and **Multidisciplinary Team**. The key findings were that there is currently no coordinated multidisciplinary team that works cooperatively together or an agreed system for the management of knee OA. The knee OA individuals' healthcare journey and treatment choices were mainly dependent on the available resources, individuals with knee OA and physician led-decisions.

10.3.1.1. Category: Individuals with Knee OA

This category summarised the codes that describe the individuals with knee OA characteristics, awareness of disease and treatments, and their ownership over their health and lifestyle. It also describes the daily rate of cases that has been estimated by the physicians, which ranges between 3 to 5 new cases. The chief complaint of individuals with knee OA was knee pain and stiffness, especially during prayers and climbing stairs that increase the knee joint's stress by requiring full knee flexion, kneeling, and a cycle of standing and setting.

(MS5/ Physician/ Line: 16)

"almost 3 or 5 cases daily."

(MS26/ Physician/ Line: 19)

"complain of stiffness and inability to pray, maybe some of them have limited range of motion."

(MS16/ Patient/ Line: 29)

"I've been praying while sitting on a chair; I cannot bend my knees."

Most of the participants demonstrate that people with knee OA's main characteristics are older age, overweight, and a mixture of male and female. One interesting comment claimed that most of the knee OA cases are Bedouins, which was assumed to be linked with their diet of heavy meals. However, Bedouins are those who live in the desert regions, and their lifestyle is believed to be hard and tough, which may be an active lifestyle, and the assumption of a link between the Bedouins diet and knee OA was not scientifically addressed.

(MS4/ Physiotherapist/ Line: 20)

"All of them are old age, working men, mostly office work and with a big belly."

(MS10/ Physician/ Line: 20)

"Obesity, females and old age. Many would come with diabetes."

(MS12/ Physician/ Line: 24)

"Overweight, old age and mostly Bedouins, due to their type of food, they always come in overweight."

When the OA individuals responded to the questions about their knee OA awareness, only a few individuals expressed some knowledge of the disease and how to manage it. For example, the participants below from the patient group talked about the action they had taken to improve their physical fitness:

(MS13/ Patient/ Line: 17)

"With being overweight and inactive, it affected me. The pain started to become worse; I started to swim to reduce the pain, and to do some exercise."

(MS17/ Patient/ Line: 67)

"I knew it was about strengthening my muscles and reducing my weight; everybody says that"

The healthcare providers indicated the lack of patient awareness about the disease. For example, several physicians and physiotherapists believed that people with knee OA avoid physical activities because they are worried and scared of the disease. Moreover, it was maintained that due to lack of awareness, individuals underestimate the problem, ignore the pain and postpone seeking medical opinions.

(MS8/ Physiotherapist/ Line: 117)

"Individuals think that if they walk, they will feel tired and hurt their knees. They misunderstand"

(MS26/ Physician/ Line: 19)

“Unfortunately, when they feel the pain, they ignore it. Then when we see them, their cases are progressing, and they are in severe or moderate stage.”

Similarly, most of the healthcare providers agreed that people with knee OA are not aware of PA's importance for their condition; instead, they asserted that OA individuals believe they should avoid PA to reduce their knee pain.

(MS10/ Physician/ Line: 116)

“The lack of awareness of the idea that individuals can do exercise or the importance of exercise.”

(MS9/ Physiotherapist/ Line: 88)

“They think sedentariness is very important to relieve pain.”

The ownership of individuals with knee OA for their health and lifestyle emerged in several responses. For example, it was indicated that individuals with knee OA were involved in the decision-making process, which allowed them to refuse treatment or request a specific one. Several knee OA participants reported that they rejected some treatments, while others were requesting referral to physiotherapy. This would suggest the patient has control and ownership of their health instead of feeling overwhelmed and out of control. Moreover, the notion of individual centred care and ownership was highlighted mainly during healthcare providers interviews, during which they often used the phrase “discuss with the patient” when describing the treatment.

(MS14/ Patient/ Line: 29)

“he told me to take the injection, but I refused,”

(MS24/ Patient/ Line: 50)

"I used to tell the doctor that I want more physiotherapy because I was feeling better. Then he refers me."

(MS10/ Physician/ Line: 37)

"We discuss conservative treatment options, like injections and orthosis."

A further indication of individuals with knee OA control of their health emerged as the physicians stated that individuals prefer to take shorter and easier treatment options. For example, knee OA individuals prefer to go to private clinics rather than taking the long journey in public health hospitals or directly access the orthopaedic consultation instead of consultation with family physicians first, who may later refer them to the orthopaedic surgeon.

(MS26/ Physician/ Line: 33)

"although the system insists that the individuals should see the family physician, but still, we see cases before them and the individuals prefer to come to us directly."

(MS5/ Physician/ Line: 77)

"many of them will go to the private clinics where they take the injections to relieve pain."

Furthermore, physiotherapists' experience of individuals with knee OA demonstrates that they show ownership of their knee OA health as they may refuse some interventions or advice.

(MS7/ Physiotherapist/ Line: 172)

"Most of the individuals will not accept what I say, and they do not listen."

(MS9/ Physiotherapist/ Line: 185)

"if you told a patient to do aerobic exercises, they will refuse"

10.3.1.2. Category: Patient journey

This category describes the typical knee OA individuals' journey in seeking medical care as it showed that they might have a different pathway depending on their own choices and the choices of their physicians. It includes the treatment options, progression of the journey from the first contact with healthcare providers, and the decision-makers referral options and presentation. Starting with the patient's initial contact with healthcare providers, there appear to be two main specialities that individuals access first, family or orthopaedic physicians.

(MS5/ Physician/ Line: 77)

"it will start from the health centre, with the family physician."

Although the family physicians argued that the healthcare system indicates they should see the individuals with knee OA first, most of the interviewed individuals reported that their first contact with healthcare was with an orthopaedic surgeon.

(MS26/ Physician/ Line: 33)

"although the system insists that the individuals should see the family physician; still, we see cases before them, and the individuals prefer to come to us directly."

(MS14/ Patient/ Line: 19)

"I went to an orthopaedic doctor."

At both family physician and orthopaedic clinics, the physicians reported that they request radiographs to diagnose the patient. After diagnosing the patient with knee OA, the physician offers the patient the first line of medical treatment, which in the physician sample interviewed is usually pain killers for six months and may be combined with advice about PA and weight loss. However, in a few cases, individuals reported that they received injections first, while others were referred to physiotherapy and medications as the first line of treatment.

(MS21/ Patient/ Line: 16)

"referred me to do an x-ray, then he told me I have OA."

(MS3/ physician/ Line: 27)

"the first thing we do is to tell them that they need to move and start exercising at least 150 minutes per week, and fast walking, if they can swim it will be better. But we also give them some medications if appropriate, to decrease their pain. So, we give them advice and painkillers and relaxants to the muscles."

(MS26/ physician/ Line: 55)

"There are many physicians who give injections as the first option, and some may delay physiotherapy or do whatever they want. It is very different and depends on the doctor."

If the first line of treatment fails to improve the patient's condition and based on the severity of OA, other treatment referrals are offered. For instance, if the individuals at the family physician clinic with moderate or severe knee OA, they might be offered a referral.

(MS12/ physician/ Line: 50)

"We deal with the mild ones. The moderate and severe, are immediately referred."

At the orthopaedic surgeon clinic, either with a referral or direct access, if the severity of knee OA is mild or moderate, the individuals might be offered injections, medications and referral to nutritionist, pain clinic, physical medicine clinic or physiotherapy. Finally, if they did not improve and their condition is severe, then the patient might be recommended for surgery.

(MS3/ physician/ Line: 37)

"I refer them to the orthopaedic department, and the orthopaedic doctor refers them to physiotherapy."

(MS4/ physician/ Line: 75)

"Physical therapy, medications and surgeries for severe, advanced cases."

(MS26/ physician/ Line: 53)

"We give them time to try then they follow up after six months, if they are not improved, then we discuss the injections or surgery, depends on the case."

If the patient accepted the referral to the physical medicine clinic, the patient may receive medications, injections, or insoles or be referred to a physiotherapist, nutritionist, or pain clinic.

(MS10/ physician/ Line: 37)

"We discuss the conservative treatment options, like injections and orthosis, maybe then we refer them to physiotherapy."

(MS10/ physician/ Line: 45)

“They are referred to the nutrition department, either I do it or anyone during the journey.”

Nevertheless, the treatment options and decision-making processes appeared to vary between physicians. Some physicians prefer to delay the physiotherapy referrals, while others offer medications and physiotherapy as adjacent approaches.

(MS24/ Patient/ Line: 30)

“First, they gave me the medications, then the injections, at last, was the referral to physiotherapy.”

(MS13/ Patient/ Line: 28)

“He gave me pain-killers and told me to go to physiotherapy.”

In summary, the treatment options given were medications, injections, physiotherapy, referral to a nutritionist and/ or surgery. However, there appears to be variation among physicians’ in terms of choices for management. The following diagram presents the multiple treatment options and patient journey in the healthcare system compiled from the interview responses (Figure 13)

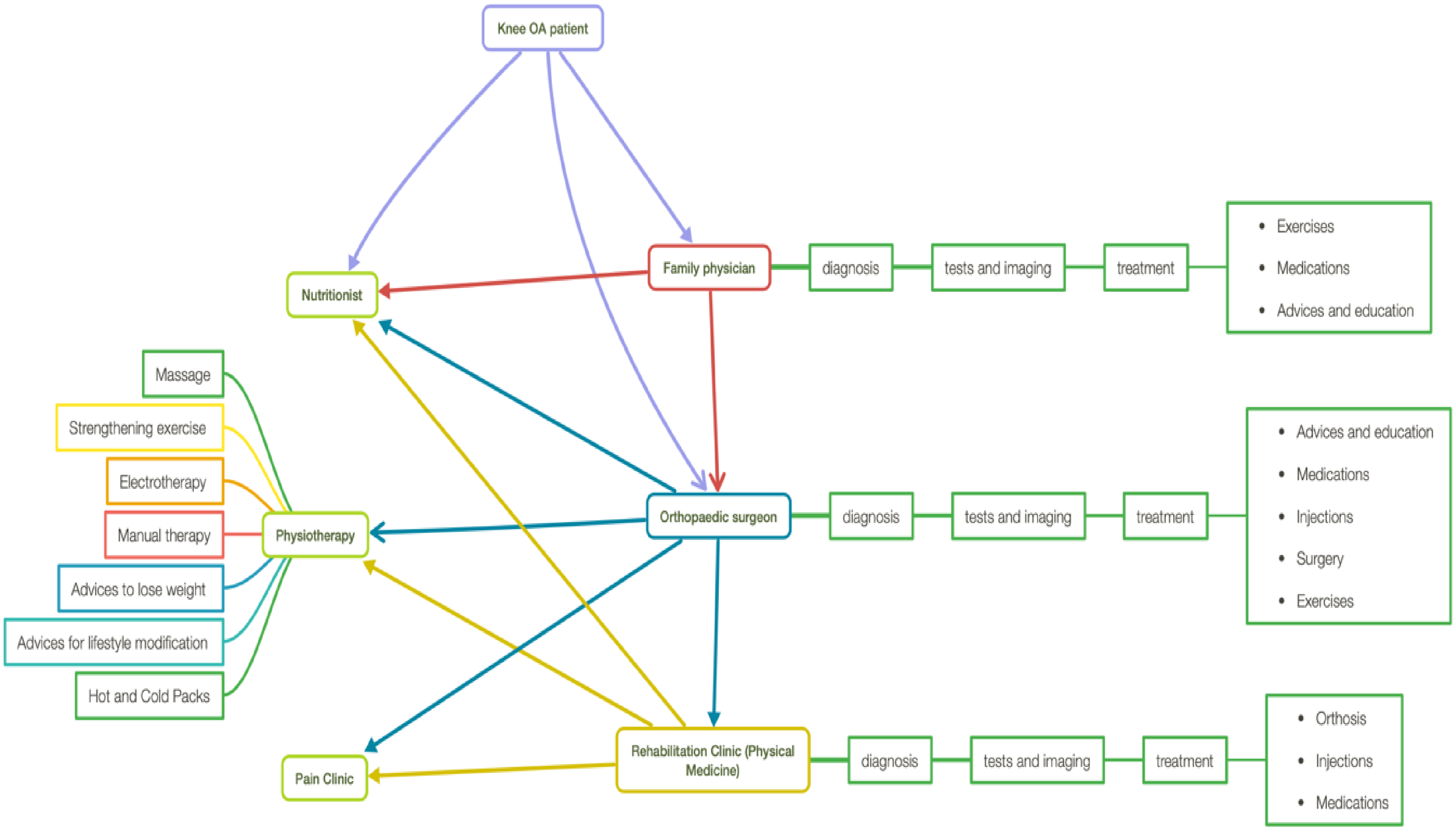

Figure 13 Treatment options and patient journey in the healthcare system in Saudi Arabia

As patient education can be considered part of the management of knee OA, the following is a discussion of physicians' efforts in educating the individuals about the disease, treatment options, weight loss, and PA. First, individuals and physicians agree that there are some efforts to educate individuals about the disease and treatment options.

(MS17/ Patient/ Line: 18)

“he explained all the progress and expectations with the disease.”

(MS3/ Physician/ Line: 39)

“The orthopaedic doctor explains to them the surgeries, medications and physiotherapy, its success and failures, and the importance of physiotherapy.”

However, one physician argued that there is insufficient time to teach the individuals because of the workload in the clinic. Also, a patient stated that the physician did not fully explain the treatment options.

(MS26/ Physician/ Line: 27)

“I guess because it is a problem in the public clinics because we see many cases and we do not have the time to explain to all of them.”

(MS6/ Patient/ Line: 31)

“but unfortunately, he did not explain what I will receive there and why I should go, and what is the treatment plan for my knees.”

Regarding physical activity education, two physicians maintained that they teach their individuals the benefits of exercise for their condition. Although one patient stated that he received advice to walk and avoid stairs, another patient maintained that there was no advice or education for improving PA to help manage knee OA.

(MS5/ Physician/ Line: 32)

"I start to explain how important exercise for them and their case and how it will improve his whole life. Then I give him exercise, and I show them pictures of how to do it, like water or land-based exercise, and the types of muscle to strength."

(MS15/ Patient/ Line: 34)

"He told me to walk, but avoid the stairs because it is painful."

(MS21/ Patient/ Line: 47)

"But no one spoke with me about physical activity."

Finally, most of the responses agreed on providing knee OA individuals with verbal advice to lose weight. However, individuals with knee OA stated that verbal advice was not enough as they still do not know how to lose weight.

(MS5/ Physician/ Line: 30)

"the first thing we do is to advise him to lose weight by about 7.5%."

(MS6/ Patient/ Line: 37)

"they advise me to lose weight, but I do not know how, but I am still trying."

(MS14/ Patient/ Line: 66)

"she told me to lose weight, but I do not know how!"

Furthermore, a small number of physicians' interviews indicated that they are aware of and adhere to the international guidelines for managing knee OA. However, there are no instructions from the administrations to follow such guidelines, and the physicians' experience and preference generally lead the patient journey.

(MS5/ Physician/ Line: 26)

“I am following international guidelines for the management of knee OA or other diseases.”

(MS26/ Physician/ Line: 39)

“There is a consensus and guidelines, so everybody is following the same treatment. But it depends on the physician, I mean it is their choice to follow or not, their experience, and what they want from the patient and how cooperative the patient, the resources. Many physicians choose whatever they like from the protocols.”

10.3.1.3. Category: Multidisciplinary team

This category outlines the availability of the multidisciplinary team and the professional relationship between healthcare providers. Firstly, most of the participants discussed the lack of a multidisciplinary team to manage knee OA cases. Although the healthcare provider appeared to be aware of the team's importance, there is seemingly no or little team planning or communication regarding patient treatment.

(MS10/ Physician/ Line: 49)

“We do not have a group or teamwork to discuss the case or plan the treatment.”

(MS3/ Physician/ Line: 71)

“We need a team, but unfortunately, we do not have, and I do not have the opportunity to follow up with individuals after I refer them.”

Interestingly, only one participant confirmed the availability of a multidisciplinary team in their hospital.

(MS8/ Physiotherapist/ Line: 85)

“Yes, Orthopedic, internal medicine, physiotherapy and nutrition. All together.”

Regardless of the limitations of the multidisciplinary team, the definition of the interprofessional role is not fully understood. For example, the gatekeeper role is overlapping, as one of the family physicians, when asked about the gatekeepers, agreed that they are the gatekeepers who control the patient’s journey, while the physical medicine physician believes that it is the orthopaedic surgeon. On the other hand, physiotherapists consider this to be the physical medicine physician.

(MS10/ Physician/ Line: 54)

“the orthopaedic doctor is responsible for the case. He decides where and when to refer; he is the leader.”

(MS7/ Physiotherapist/ Line: 43)

“the rehabilitation doctor is controlling the case, and he is in contact with other healthcare providers, not the physiotherapist.”

The professional relationship was another issue raised which indicated a lack of professional communication between healthcare providers. When asked about the communication between them and the physicians, physiotherapists negatively replied to the existence of such a relationship. However, a physiotherapist indicated that there is contact between physiotherapists and physicians at the discharge of individuals.

(MS1/ Physiotherapist/ Line: 54)

“never, they only refer without any communications.”

(MS10/ Physician/ Line: 74)

"because of the low quality of referrals and no communications, the individuals will not understand the aim of physiotherapy, and the therapist misses the aim with the individuals."

(MS4/ Physiotherapist/ Line: 89)

"before discharging the individuals from physiotherapy, we contact the doctor and discuss everything with him the decision it is his call in the end."

In terms of interprofessional roles, there was a negative view of the physiotherapist's roles as the physicians acknowledged that, excluding family and physical medicine physicians, the role of physiotherapy is not well-known among other physicians' specialities. Unexpectedly, the interviewed orthopaedic surgeon stated that they provide physiotherapists with a specific treatment plan, which could be perceived as a lack of awareness and interfering with physiotherapists autonomy.

(MS10/ Physician/ Line: 42)

"Some specialities do not understand the idea and importance of physiotherapy."

(MS26/ Physician/ Line: 72)

"We write knee OA only, bilateral or not, and what treatment they should do like the exercise and electrotherapy specifically."

The physiotherapists raised the issue of interprofessional roles and autonomy as they criticised the referral reports. In particular, the reports were detailed with instructions for physiotherapists on the exact type of exercise they can use, or may alternatively lack details on the case.

(MS7/ Physiotherapist/ Line: 42)

"Some may write the types of exercise they want us to do for the patient and what not to do; they interfere with our role."

"they write 'reason for referral is to exercise', but without details or history. Most of the cases we see are misdiagnosed."

A recurrent issue in the interviews raised by healthcare providers was shifting the patient's responsibility by referrals. Firstly, it was claimed by physiotherapists that physicians refer severe cases to shift their responsibility to them. However, physicians disagree with the previous claim as they declared that they refer the severe cases specifically for a pre-surgery program. This misunderstanding between the healthcare providers could be a result of the lack of communication.

(MS1/ Physiotherapist/ Line: 34)

"most of them just to delay it because they even sometimes refer severe cases so that they can do anything until their surgery. The most important thing for them is that the patient came out of his hands or responsibility."

(MS8/ Physiotherapist/ Line: 21)

"some doctors will just send them to physiotherapy to throw the responsibility on them."

(MS26/ Physician/ Line: 68)

"We refer him to physiotherapy specifically for the pre-surgery program. We follow a pre-surgery protocol here."

The second responsibility shift appeared in the referral to gyms by physiotherapists and physicians instead of treatment in physiotherapy clinics. However, it is unknown if the referral to gyms was suggested to the patient after discharge from physiotherapy or was part of the patient education for a healthy lifestyle. Moreover, the referrals to gyms may occur in hospitals where there are a lack physiotherapy clinics.

(MS1/ Physiotherapist/ Line: 28)

"I advise my individuals to go to private gyms or swim."

(MS11/ Personal trainer/ Line: 23)

"There are people who had been seen by a physiotherapist and were instructed to go strengthen specific muscle."

(MS26/ Physician/ Line: 73)

"Many physicians are busy, and they do not provide a good service to the individuals, so they just tell the individuals that they need to lose weight and to move more, but wherever they want, even if it is in the gym."

(MS9/ Physiotherapist/ Line: 25)

"Some doctors tell the individuals 'go strengthen your legs' that's it!"

10.3.2. Theme 2: Physiotherapy service and International guidelines practice for knee OA

This theme focused on the different issues related to the physiotherapy service, such as the number and organisation of clinics, treatment protocols and adherence to treatment guidelines for knee osteoarthritis. Moreover, it reports physiotherapist justifications for the lack of adherence to the guidelines and solutions to promote guideline adherence. The theme comprised of three categories: **Physiotherapy service**; **Physiotherapy Treatment,** and **International guidelines practice**. Key findings from this theme were a lack of physiotherapy clinics, delayed referrals, limited autonomy and limited use of treatment guidelines by physiotherapists.

10.3.2.1. Category: Physiotherapy service

Most participants reported that physiotherapy clinics at primary healthcare centres are not available and not part of the service. The physicians were hoping to have physiotherapy resources at their centres.

(MS5/ Physician/ Line: 44):

> *"I hope, and I wish, I know it is the right thing to do, but I wish if we have a physiotherapy centre in every GP practice or health centre. Unfortunately, we do not have"*

(MS3/ Physician/ Line: 48):

> *"There is no physiotherapy clinic at our health centre, and there is no public physiotherapy clinic in the area so I cannot even refer them."*

While there is an issue with resources, individuals can only be referred to hospitals to access and receive physiotherapy treatment. There is no direct access or self-referral to physiotherapy, and only the orthopaedic physician has the authority to refer the individuals.

(MS12/ Physician/ Line: 62):

> *"I have to refer them to orthopaedic, and they can refer them to physiotherapy."*

(MS4/ Physiotherapist/ Line: 52):

> *"there must be referrals; they cannot see us without it."*

Consequently, due to the lack of physiotherapy clinics at primary healthcare centres and the current referral system, the patient journey was believed by knee OA individuals and healthcare providers to take a long duration. For instance, it may take months to be seen initially by the family physician first, then an onwards referral to the orthopaedic surgeon, followed by a physiotherapy referral. The individuals and healthcare providers maintained that the patient's condition might worsen or lead to withdrawal from the service due to the long journey.

(MS3/ Physician/ Line: 61):

> *"because until I refer to orthopaedic and then to physiotherapy, they all take a long time, in months! So eventually we find the cases will worsen until that time."*

(MS6/ Patient/ Line: 41):

> *"to be seen by the doctors took a very long time, and even physiotherapy gave me an appointment after several months of the referrals."*

Discharge from physiotherapy also appears to vary. It can be from the patient self-discharging or by physiotherapists. Individuals might discontinue treatment depending on their treatment response, or they might withdraw due to the long journey and delayed appointments or lack of adherence to treatment.

(MS7/ Physiotherapist/ Line: 38):

> *"Regards the discharge, we have two pathways for discharge, either the patient feels better or worse and discontinues by himself, without informing us. Or a formal discharge."*

(MS1/ Physiotherapist/ Line: 47):

> *"because advanced cases do not improve with physiotherapy, so they withdraw."*

(MS12/ Physician/ Line: 178):

> *"When the patient sees the delay in the appointment after a few months or weeks, and the procrastination, he might withdraw."*

Regarding the physiotherapist's autonomy, the physiotherapists' interviews indicated three issues; lack of direct access, the lack of confidence in the ability to diagnose, and physicians' interference with physiotherapy treatments. Firstly, individuals cannot access physiotherapy service without a referral; there is no direct access or self-referral to the physiotherapy. Secondly, the physiotherapists interviewed did not think they were qualified to diagnose the individuals. The physiotherapists maintained that they were trained to treat only, not to diagnose.

(MS1/ Physiotherapist / Line: 75):

"how do you know that he has knee OA? referrals are a must."

(MS7/ Physiotherapist / Line: 63):

"Because as physiotherapists we want to treat only, we understand in our job, but we do not understand in diagnosis that much! The doctors are better."

Thirdly, the issue of physicians' interference with the treatment protocol offered by physiotherapists to the individuals was raised. It was identified several times that the physiotherapists could create their treatment protocol based on their experiences and education or follow specific protocols offered by the hospitals. However, physicians could challenge their autonomy as they may write the treatment plan within the referral reports.

(MS7/ Physiotherapist / Line: 155):

"The hospital provides us with methods or protocols for treating a variety of diseases, but we have the choice to use it or not."

(MS9/ Physiotherapist / Line: 170):

“Mostly, they are based on my education and experience. When I take courses about the tape, for example, then I try it, and I see positive results, I keep doing it. Like this.”

10.3.2.2. Category: Physiotherapy Treatment

During the physiotherapy treatment session, the management of knee OA cases was primarily based on the physiotherapists' experience and preferences.

(MS1/ Physiotherapists/ Line: 54)

“I treat my individuals based on my way, my experience and what worked and what did not “

(MS4/ Physiotherapists/ Line: 68)

“I depend on my experience and my basic university education.”

The patient was involved in the decision-making processes. Several physiotherapists maintained that the individuals must accept their treatment protocol since OA individuals can refuse any intervention.

(MS1/ Physiotherapists/ Line: 43)

“individuals do not accept such treatment.”

(MS7/ Physiotherapists/ Line: 56)

“I rely on the patient himself first; then if they do not accept many methods, I give him few.”

Physiotherapists and individuals discussed the treatment plan they received or offered to the individuals. The priority and core treatments were strengthening exercises and electrotherapy.

(MS1/ Physiotherapists/ Line: 56)

"Mostly, his treatment will be muscle strengthening along with mobilization with exercise, which I see as useful and successful, In addition to electrotherapy to relieve pain."

(MS14/ Patient/ Line:)

"They gave me strengthening exercises, then electrotherapy."

Moreover, individuals were educated about the importance of losing weight and PA for their disease. Specifically, individuals were educated about the type of exercise they can do or avoid. This was delivered by using media such as photos and videos or verbal advice.

(MS7/ Physiotherapists/ Line: 35)

"Yes, I do, and I show the individuals some photos and videos on how to do the exercises. In addition, every couple of visits, I give him new exercises and new ideas."

Additionally, two knee OA individuals reported that they were educated with lifestyle modification and to avoid wearing high heels.

(MS17/ Patient/ Line: 72)

"Yes, the physiotherapist, he used to give me advice about lifestyle modification and to avoid vigorous activities."

(MS13/ Patient/ Line:34)

"[…] once one of them told me not to wear high heels."

However, other education topics were only reported by two physiotherapists. For example, one physiotherapist claimed that they educate their individuals about weight loss, while another stated that they educate their individuals about the disease. None of the physiotherapists or OA individuals participants reported the discussion or education of physiotherapy treatment options with the individuals.

(MS4/ Physiotherapists/ Line: 31)

"I do focus on his weight, and I give them some advice to lose weight."

(MS1/ Physiotherapists/ Line: 56)

"First, I teach the patient the degree of OA he has and the stage of the treatment."

10.3.2.3. Category: International guidelines practice

From the interview transcripts, it appears that most of the interviewed physiotherapists did not follow the guidelines and recommendations for managing knee OA. Moreover, one of the physiotherapists demonstrated a lack of knowledge about treatment and physical activity guidelines for knee OA, in which they believed that individuals are not advised to walk. While only one participant claimed that they read the guidelines.

(MS4/ Physiotherapist / Line: 134):

"No, I do not read it, and I do not refer back to it."

(MS9/ Physiotherapist / Line: 191):

"if there is one who is working with the guidelines, there will be nine who do not."

(MS1/Physiotherapy/ Line: 120)

"with knee OA patient, your task with him at the beginning and middle is that you do not want him to walk, you do not want him to press on his knees and put pressure on it."

Physiotherapists discussed their barriers and reasons not to follow guidelines. For example, several physiotherapy participants claimed that they are not adapted for, or applicable in, Saudi Arabian culture.

(MS9/ Physiotherapists/ Line: 171)

"Most of the guidelines are not applicable in Saudi Arabia […], Our culture is different; individuals are different; resources are different. Their studies cannot be applied to our individuals. Their environment is perfect, not like ours."

(MS1/ Physiotherapists/ Line: 195)

"because some of it is not applicable in our society."

One physiotherapist criticised the lack of time for applying the recommendations and the lack of ability to understand the guidelines by physiotherapists. In addition, the personal preference to not follow the guidelines was another reason not to follow them.

(MS4/ Physiotherapists/ Line: 98)

"I have only 30 minutes with the patient; I cannot cover all these issues!"

(MS9/ Physiotherapists/ Line: 58)

"First of all, not all physiotherapists can understand this guideline."

(MS7/ Physiotherapists/ Line: 86)

"But only personal preference, I prefer it this way."

The lack of monitoring and observations from the administrator at hospitals, such as department leaders, is one of the causes of the lack of adherence to the guidelines.

Furthermore, the physiotherapists reported that patients might decline guidelines based interventions, which was reported as a barrier to adherence.

(MS9/ Physiotherapists/ Line: 165)

> *“No one will care! Be realistic! If there is monitoring, observation or instructions to follow something, then everyone will do it, but we do not!”*

(MS9/ Physiotherapists/ Line: 147)

> *“If you told the patient to walk with their pain, they will not come back!”*

(MS7/ Physiotherapists/ Line: 136)

> *“Every patient is different, the guidelines are not appropriate for all of them, and the patient’s commitment is different.”*

A physiotherapist argued that adherence to the guidelines would improve the healthcare service, yet that many physiotherapists only work to get paid, and therefore have no interest in the quality of service.

(MS8/ Physiotherapists/ Line: 114)

> *“many of them are just working just for the work. Only for the salary. They do not care about the improvement of service.”*

Physiotherapists behaviour towards the guidelines may be based on an external locus of control. To elaborate, the majority believed that there must be instructions from the Ministry of Health and administrators to follow the guidelines; otherwise, no one will follow these guidelines.

(MS4/ Physiotherapists/ Line: 125)

> *"There must be instructions and orders from their leads and administrations to follow the guidelines."*

(MS7/ Physiotherapists/ Line: 124)

> *"the only thing that makes us follow our protocol is the hospital itself; otherwise, we will not have promotions, and there will be sanctions."*

(MS9/ Physiotherapists/ Line: 90)

> *"there must be instructions to do so, but the guidelines must adapt to our culture."*

10.3.3. Theme 3: The Culture of Physical Inactivity

This theme explored participants perception of PA in non-arthritic healthy population and knee OA individuals while identifying barriers to physical activity and suggestions to increase it. It discuss issues around the influence of Saudi culture and lifestyle that affect their physical activity levels, such as gender and generational differences. The theme introduces methods and responsibility to promote PA and current efforts to promote PA and the attitude to change. The theme comprises five categories: **Perceptions of PA, Generational differences, Gender differences, Promotion of PA** and **Lifestyle**. The key findings were several barriers that led to the status of physical inactivity, and they were more significant with the females.

10.3.3.1. Category: Perceptions of PA

The overarching perception towards participation in physical activity among a sample of knee OA individuals and non-arthritic healthy individuals in Saudi Arabia is that the society is physically inactive. The participants believe that PA is not considered part of the Saudi Arabian culture, and the population awareness of PA's importance is inadequate. Individuals with knee OA and non-arthritic healthy participants have highlighted that this society has always been inactive.

(MS19/ Healthy/ Line: 15)

"I live with people who are employers or private business owners; there is nothing called exercise in their life."

(MS17/ patient/ Line: 95)

"Our population is spoiled; they do not practice any exercise."

Indeed, physicians and physiotherapists who have assessed the patient's physical activity also maintained that their individuals were inactive.

(MS1/ Physiotherapist/ Line: 169)

"mostly, the individuals are used to being inactive, their culture and personality."

(MS12/ Physician/ Line: 117)

"The majority are living a sedentary lifestyle; they do not care about this stuff."

Similarly, the personal trainer and the teacher had a similar opinion on the community participation in physical activity and exercise; they believed that Saudi society suffers from a lack of time and awareness of the importance of PA

(MS11/ Personal trainer/ Line: 75-80)

"They do not understand the importance of exercise."

"Many of them have a lack of awareness."

(MS20/ Teacher/ Line: 77-79)

"Try yourself and sit with a group of people and ask them how many do exercise or any kind of physical activity; no one does it, very rare."

"They are busy with their life. Who does it among us except a few people?"

10.3.3.2. Category: Generational differences

The participants' responses revealed a remarkable stereotyped image of senior adults as they view them as being old and sedentary with minimum activity. Among the non-arthritic healthy population aged over 50 years and OA group of participants, the majority believed that they are too old for doing physical activity and were observed to refer to themselves as "old aged people".

(MS6/ Patient/ Line: 87)

"I guess most of the individuals or older aged adults are like this. Do you want them to be young again and do exercise normally!"

(MS19/ Healthy/ Line: 34)

"They say, I worked enough, and at my age, I should be resting. What do I want with exercise and physical activity!"

Other participants indicated that there is a stereotyped image of senior adults, where they are described as inactive, sedentary and 'near-death'.

(MS7/ Physiotherapist/ Line: 96)

"I mean they would say that they are old and near death, and that is it, this is what written for me, which is naturals."

(MS11/ Personal trainer/ Line: 90)

"They lost it. Old is old."

Furthermore, gym participation for senior adults is considered very rare and mainly for treatments for specific injuries or diseases.

(MS11/ Personal trainer/ Line: 17)

"I did see old people. But most of those old people come to the gym for treatment from an injury or disease."

(MS18/ Healthy/ Line: 17)

"I do not go to the gym anymore."

On the contrary, the stereotyped image and view of PA in teens and young adults are more favourable. A small number of participants assumed that the new generation is more aware and educated about the importance of PA.

(MS11/ Personal trainer/ Line: 93)

"The new generation is better; they have awareness and knowledge."

(MS23/ Healthy/ Line: 67)

"The new generation of social media, they are more interested and more open."

However, the sports teacher interviewed disagreed and argued that students are not aware or interested in PA and exercise, but they only want to practice one PA type (e.g. football). They continued to maintain that only a minority of students are practicing exercises or are registered with gyms.

(MS20/ Teacher/ Line: 16-17-75)

"Unfortunately, it is a disaster."

"But unfortunately, among a whole patch of students, maybe one or no one is doing exercises or is registered with a gym."

"The students get mad when I teach them and don't let them play football like the others."

10.3.3.3. Category: Gender differences

Females in Saudi Arabia suffer from gender-specific barriers to physical activity. Most of the participant groups reported several conservative culture barriers such as the inability to jog or run outside and wearing very conservative clothes (e.g., abaya: the black cover of the face and body) that hinder their movement. A female participant also believed that due to the conservative environment, exercising outdoor is not allowed.

(MS7/ Physiotherapist/ Line: 124-125)

"I am also worried if I can say that but also the Abaya, I feel that it is a big problem and obstacle for them. They have to wear them if they want to walk outside so that the hot weather will be worse in them."

(MS23/ Healthy/ Line: 52)

"We also cannot do exercise outdoors because it is a conservative country."

Similarly, a participant felt that as a conservative community, females are not encouraged to be seen walking outside as males might be embarrassed. Until recently, females did not have sports classes in their schools, and they were not allowed to practice exercise at school.

(MS15/ Patient/ Line: 77)

"If they see a woman exercising, they will say that 'we saw your mother, wife or your family walking'. Guys do not like hearing that, so, they do not encourage us to exercise."

(MS15/ Patient/ Line: 67)

"For women, they are just allowed sport or exercise classes in schools. It is not part of the culture."

Regardless of the conservative culture barriers, females have other cultural limitations and barriers that may not affect males. For example, the lack of time due to their responsibility as a housewife, unsupportive husbands and/ or lack of access to transportation were reported as significant barriers to their physical activity.

(MS14/ Patient/ Line: 97)

"My husband does not support me. I mean, he makes me responsible for all the house-work and the kids, he says exercise is not important for me."

(MS23/ Healthy/ Line: 27)

"When I try to adjust and find time for it, my husband says we do not have time for this. It is not necessary."

(MS18/ Healthy/ Line: 86)

"The transport also a problem for women."

Lastly, there is an agreement among participants that although the best choice to practice physical activity is at female-only gyms, they are expensive and rarely available.

(MS15/ Patient/ Line: 66)

"gyms, maybe for men it is better, but for women, it does not exist or is overpriced, too expensive."

(MS11/ Personal trainer/ Line: 121)

"Regarding the females, it is different, the prices are very high, too much, and very limited.

10.3.3.4. Category: Promotion of PA

Participants reported a small number of governmental efforts to support and facilitate PA in the community, such as building walkways (walking tracks) and campaigns. Moreover, they have recently allowed women to drive and included sports classes in female schools.

(MS8/ Physiotherapist/ Line: 106)

"The government have provided everything. Places to walk everywhere."

(MS20/ Teacher/ Line: 58)

"But it is better now, they allowed women to drive, there are classes at their schools."

(MS18/ Healthy/ Line: 76)

"they always do campaigns to encourage us to exercise and be physically active."

However, several participants disagree with previous statements, as they believe that there is a lack of campaigns and efforts to promote PA in the community. Moreover, the sports teacher argued that there is a lack of seriousness in sports education, especially in assigning unqualified teachers in primary schools, while sports classes are believed to be only for playing football.

(MS11/ Personal trainer/ Line: 58)

"There are no campaigns or very few."

(MS20/ Teacher/ Line: 89)

"They assign lazy and bad teachers to the primary school because the workload is much less, and the students are easier there."

(MS20/ Teacher/ Line: 73)

"The teachers do not do anything, only play football."

Regarding healthcare providers efforts to promote PA in the community, it has been maintained that there are a small number of campaigns and efforts to promote PA in the community. However, a participant claims that they are unable to deliver the message to promote PA, as the ages they deal with in the campaigns are younger than most of the individuals.

(MS11/ Personal trainer/ Line: 59)

"some gyms participate with physical therapy departments to create campaigns for group walking, but it happened only once."

(MS1/ Physiotherapist/ Line: 159)

"We encourage and teach people on the benefits and harms of physical activity through lectures and campaigns at walkways or malls, 4 or 5 times a year."

(MS1/ Physiotherapist/ Line: 168)

"Mostly the ages we see or deal with, in the campaigns are younger than the individuals."

The interview responses have revealed a negative attitude towards the possibility of changing PA in the community. Several participants believed that the community would not accept the idea of PA.

(MS20/ Teacher/ Line: 45)

"Forget about them; they will not do it. We have a problem."

(MS6/ Patient/ Line: 67)

"They barely walk, and not everybody accepts this idea."

(MS8/ Physiotherapist/ Line: 103)

"It is difficult to teach them and make them understand."

However, regardless of previous claims, the interview responses show that the community is willing to change. Several participants believe that there are changes in the awareness and PA participation in the community, and others are eager to improve their PA.

(MS12/ Physician / Line: 139)

"But honestly, recently they are improving regards walking."

(MS21/ Patient / Line: 58)

"Although there are people who started to walk inside shopping malls, as an alternative."

Suggestions have been made to promote PA in the community. First, participants suggest that the change must start from a younger age and that the schools must improve sports modules by assigning qualified teachers and assigning pass or fail to the module. Then, the awareness of the community must improve through campaigns and walking programmes.

(MS10/ Physician/ Line: 130)

"The change must start from an early age; we must teach the new generation to adapt to the variety of foods, then by managing the time and improving the lifestyle."

(MS20/ Teacher/ Line: 69)

"making the module more important by applying fail or pass to it, otherwise, no one will care."

(MS11/ Personal trainer/ Line: 103)

"Campaigns everywhere. Walking programs, they can take a group of people to walk together."

There is also a need to provide more resources, such as building more public gyms and reasonably priced private ones.

(MS17/ Patient/ Line: 90)

"They need more support in terms of the resources as providing free public exercise machines."

Interestingly, several participants suggested that there should be rewards for the community for being physically active. These rewards were described as discounts, incentives or increased work salaries.

(MS19/ Healthy/ Line: 48)

"The only reason for physical activity is work. There must be some reward or a reason for the movement and activity; otherwise, they will not exercise or even walk."

(MS20/ Teacher/ Line: 105)

"People needs discounts or advantages. There must be a reward."

Although it has been suggested that physiotherapists are responsible for educating the community and OA individuals about PA, other participants believed that it is the responsibility of the healthcare team and the community.

(MS12/ Physician/ Line: 161)

"Supposedly, physiotherapy."

(MS1/ Physiotherapist/ Line: 140)

"it is the responsibility of the doctor and the medical team, nutrition and orthopaedics."

(MS11/ Personal trainer/ Line: 106)

"This is the responsibility of the whole community."

10.3.3.5. Category: Lifestyle

There is a lack of awareness in the community regarding the concept of PA as it was maintained that the community had incorrect beliefs about PA, especially at an older age.

(MS11/ Personal trainer/ Line: 72)

"They would say 'why do I want to do exercise? What is it for? What I want to be at this age'. Why they want to feel tired and carry weights!"

(MS15/ Patient/ Line: 69)

"My son, a woman at my age, how can she exercise! I cannot go to the gym or by myself!"

The responses to the question about the participants' PA level confirmed the previous claim about community awareness, as it shows that individuals with knee OA and non-arthritic healthy participants rarely engage in PA. Exercise and PA were not part of the lifestyle and culture; it is not a priority or habit.

(MS25/ Healthy/ Line: 16)

"I walk only, but not regularly. Only at work, but for long-distances."

(MS22/ Healthy/ Line: 45)

"Exercise is not a priority for us; studying is a priority."

(MS11/ Personal trainer/ Line: 91)

"It is not part of their life or their interest; they do not appreciate its importance or the harms of being inactive."

The main reason to do PA was related to appearance, especially for younger individuals. For older ages, PA may only happen if it was in the form of work for the job.

(MS11/ Personal trainer/ Line: 86)

"When the kids grow up, they start to take care of their looks and bodies; they want to be muscular. Teens, you know."

(MS23/ Healthy/ Line: 20)

"To be fit and 'sexy'. For my body mainly"

(MS19/ Healthy/ Line: 17)

"If we do not have work to do, you will find us sleeping or drinking tea and doing nothing. But if we have work or task to do, you will find us working even if we are 80 years old."

Numerous barriers were identified that may affect the PA level in non-arthritic healthy participants and individuals with knee OA. Individuals with knee OA stated that their knee pain, busy lifestyle and their self-image had affected their participation in PA activities.

(MS13/ Patient/ Line: 16)

"When I used to exercise, there was pain and tightness. That time, it was my daughters' weddings, so I stopped exercising for a year."

(MS14/ Patient/ Line: 113)

"I do not want to walk outside because when I limp, people will look at me and say I am young but look like an old woman."

Regarding environmental and social barriers, the majority of those who responded to this item agreed that the hot weather was a significant obstacle that affected their ability and willingness to do PA. Respondents were asked to suggest other reasons for physical inactivity. One participant mentioned the lack of public transport and the use of private cars for commuting which is considered a challenge to engaging in PA.

(MS10/ Physician/ Line: 111)

"First thing would be the hot weather; it plays an important role."

(MS11/ Personal trainer/ Line: 115)

"Transport, for example, there is no public transport or walking, everything is by car, not like Europe."

Furthermore, non-arthritic healthy participants' and individuals with knee OA's previous negative experience with PA and lack of motivation have been reported as barriers. One non-arthritic healthy participant reflected his experience with exercise, in which he stated that it is socially inappropriate to walk outside in the neighbourhood, as others would think that it invades the privacy of their houses.

(MS18/ Healthy/ Line: 79)

"Laziness, not excited! There is no motivation."

(MS19/ Healthy/ Line: 28)

"When I go out and walk out in the neighbourhood, it is inappropriate to walk in front of other peoples' homes. The people would say 'why is he walking here; it is our privacy and inappropriate'."

Finally, walkways were claimed to be inappropriately designed and caused pain; therefore, this activity was generally avoided.

(MS9/ Physiotherapist/ Line: 120)

"They are available everywhere, but they are bad and cause problems. People who walk there may have pain and never come back!"

10.3.4. Theme 4: Participants views of the healthcare system for individuals with knee OA

This theme demonstrates the participants' opinions and views of the healthcare system from their experience and beliefs. First, the attitude of individuals, physicians and personal trainer to physiotherapy were discussed, followed by the response or effectiveness of treatment as reported by knee OA individuals and their experience with healthcare providers. Finally, several limitations and solutions to improve the healthcare service that had been identified by the participants are reported. The theme compromises four categories; **Previous experience with healthcare, Response to treatment, Limitations of healthcare system, and Attitude towards physiotherapy**. The key findings were the limitations in healthcare service that led to the individuals with knee OA's poor experiences, such as the delayed access to services due to heavy workloads and the repetition of diagnostic tests and treatment interventions by physicians. Moreover, it revealed an issue with the lack of awareness of the role of physiotherapy in knee OA.

10.3.4.1. Category: Previous experience with healthcare

The individuals' experience with the healthcare system was generally considered unsatisfactory, mainly due to the delay of appointments and improper delivery of advice to individuals. It was stated in multiple interviews that the healthcare-seeking journey is long, and there are delays in accessing healthcare services. Moreover, one patient maintained that he did not understand the advice, as they were verbal suggestions only.

(MS17/ Patient/ Line: 32)

"The doctors' advice was only verbal, and I forgot them, he should have written them at least, or given me videos!"

During the physiotherapy treatment session, one patient reported that they felt bored with the type of intervention they provide, as he believed that they were outdated. Whereas another patient reported that they did not educate him about the treatment options so that he could lose his fear of treatment.

(MS17/ Patient/ Line: 45)

"the physiotherapy was very boring, and they use old methods."

(MS6/ Patient/ Line: 66)

"in physiotherapy, they could have explained to me what it is, and how it can benefit me, so I can lose my fear, or at least if I meet a physiotherapist who can do so."

10.3.4.2. Category: Response to treatment

Several respondents argued that they did not benefit from physiotherapy treatment, while others stated the opposite as they felt better after physiotherapy.

(MS13/ Patient/ Line: 137)

"I did not feel any reduction in pain or any effect. Nothing changed. But I am also becoming less active."

(MS26/ Physician/ Line: 93)

"what I hear from the individuals is that they do not get better with physiotherapy, and they do not receive a lot."

(MS14/ Patient/ Line: 99)

"I felt 20% better with physiotherapy."

(MS15/ Patient/ Line: 127)

"I feel 90% better after the physiotherapy treatment and the injections,"

On the other hand, the medical treatments were reported by a patient as successful, especially injections. However, the individuals' experience with treatment in gyms were not favourable; instead, those who received such treatment stated that their pain increased.

(MS14/ Patient/ Line: 38)

> *"After I was diagnosed with OA, I went to the gym to lose weight, but it is not suitable at all! The pain increased, and the coach does not understand my problem, she gave me exercises that I cannot do."*

10.3.4.3. Category: Limitations of healthcare system

There are several reported limitations in the healthcare system, such as the variation of care and the lack of an agreed system for healthcare delivery, the heavy workload, lack of monitoring and delays in accessing services. Firstly, physicians have reported that even with the availability of a treatment protocol, the decision to follow or choose a different management approach is based on the physician's judgment. Others have also confirmed this as they argue that there is no agreed system for managing knee OA cases, which leads to a variation of care.

(MS10/ Physician/ Line: 158)

> *"There is no clear system for management"*

(MS26/ Physician/ Line: 167)

> *"There is a consensus and guideline, so everybody is following the same treatment. But it depends on the physician, I mean it is their choice to follow or not, their experience, and what they want from the patient and how cooperative the patient, the resources. Many physicians choose whatever they like from the protocols."*

Moreover, physicians complained about the heavy workload in their clinics, which they express as the primary problem that leads to the delays in the clinics along with the lack of agreed systems for healthcare delivery.

(MS26/ Physician/ Line: 168)

> *"Unfortunately, the primary healthcare or centres are inactive, they just refer to us, and the load is very high. The appointment also takes a long time."*

Physicians argued that due to the lack of a system, there is a repetition of tests and treatments that cause a delay in the healthcare service.

(MS12/ Physician/ Line: 134)

> *"The orthopaedic doctor will repeat the same tests that we ran, the same imaging, the time is lost while these things happen, until the patient receives the treatment."*

The individuals also complained about the delayed appointments, which led them to withdraw from receiving healthcare.

(MS6/ Patient/ Line: 166)

> *"to be seen by the doctors took a very long time, and even physiotherapy gave me an appointment after several months of the referrals. I did not even go to that"*

Regarding physiotherapy, several therapists also maintained that the referral to physiotherapy is delayed.

(MS4/ Physiotherapist/ Line: 173)

> *"individuals will take a long time to be seen by physiotherapists. Because there is a lack of seriousness when it comes to physiotherapy referrals."*

Finally, the lack of monitoring of the healthcare service in Saudi Arabia has been purported as a reason not to follow the treatment guidelines. Indeed, the individuals may receive inappropriate treatment that is not monitored by the administrators in the hospitals (e.g. supervisors, department managers, quality monitors, etc.)

(MS9/ Physiotherapist/ Line: 187)

> *"the patient may take ten sessions without any improvements, no one knows! No"*

10.3.4.4. Category: Attitude towards physiotherapy

Although individuals were requesting referrals to physiotherapy, they were unaware of the role of physiotherapy for their condition.

(MS26/ Physician/ Line: 173)

> *"[…] Sometimes they request physiotherapy, but they do not know what they are going the receive there."*

(MS3/ Physician/ Line: 78)

> *"many individuals were requesting a referral to physiotherapy or orthopaedic surgeons. But they are unaware of their role in the treatment."*

Unexpectedly, the physicians' attitude was similar, as they maintain that the physicians are not aware or interested in physiotherapy treatments. However, there are some medical specialities that may be more aware of physiotherapists' roles in the treatment of knee OA, such as physical medicine and family physicians. Another interesting observation was that the personal trainer believed that other personal trainers could treat individuals in the same way as a physiotherapist, indicating a lack of awareness of the role and training of physiotherapists.

(MS12/ Physician/ Line: 139)

"personally, and between the family medicine doctors, we totally respect the physiotherapy work, the family medicine doctors know the importance of physiotherapy and nutrition. In the Saudi board, they are focusing on the importance of these specialities."

(MS11/ Personal trainer/ Line: 128)

"We also have people who can treat like physiotherapy."

11. Chapter 11: Discussion

The second phase of this study aimed to explain the results of phase 1 by exploring the participants' perspectives on the opportunities and barriers to physical activity in Saudi Arabia for individuals with knee OA. In addition, the second phase aimed to explore physiotherapists attitude and barriers towards clinical practice guidelines in Saudi Arabia. A qualitative design in the form of semi-structured interviews was carried out, which included physicians, physiotherapists, individuals with knee OA, non-arthritic healthy participants, personal trainer and school-teacher.

The findings of the second phase of this study suggest that there are several barriers to PA in individuals with knee OA, with limited efforts to promote PA in people with knee OA in Saudi Arabia. In addition, some physicians believed that it is the responsibility of physiotherapists to educate the patients as well as the population about the benefits of PA, while other participants maintain that it is the responsibility of the whole community. The participants made several recommendations to promote PA amongst the general public and amongst OA individuals, such as providing rewards, better access to gyms and improved PA education of young adults and children through their schooling.

Moreover, the study found that physiotherapists were inadequately following the clinical practice guidelines for knee OA, which was attributed to several identified barriers such as lack of treatment session time, awareness and monitoring. Some physiotherapists also argued that the clinical practice guidelines were not applicable in the culture of Saudi Arabia, and some knee OA individuals declined guideline-based interventions. Moreover, the current healthcare service perceived as a poor experience for some individuals with knee OA during their treatment journey. The study found several limitations in the individuals’ journey for seeking healthcare, such as the lack of an agreed system of healthcare delivery, referral delays and low quality of service. The following sections discuss and interpret the results with the current literature, according to the aims of the second phase of this study.

11.1. Participants perspectives on the opportunities and barriers to physical activity in Saudi Arabia for individuals with knee osteoarthritis.

Overall, there were varying levels of support for PA by healthcare providers, and several barriers led to physical inactivity in a sample of individuals with knee OA and non-arthritic healthy individuals in Saudi Arabia.

11.1.1. Barriers to PA

The current study has shown that lack of PA and the number of barriers to PA, such as the weather, lack of awareness and social support, suggests that this may be a wider cultural and environmental issue in Saudi Arabia. These findings are in agreement with the literature about the prevalence of physical inactivity in Saudi Arabia (Al-Hazzaa 2002; Al-Nozha et al. 2007; Al-hazzaa 2018; Alqahtani et al. 2020). Participants in this study also appear to hold similar perceptions to the previous literature in terms of low level of physical activity in the Saudi population that was attributed to limited awareness of the importance of PA, not being a part of the lifestyle and culture, and not a priority or a habit Arabia (Al-Hazzaa 2002; Al-Nozha et al. 2007; Al-hazzaa 2018; Alqahtani et al. 2020). In addition to the knee pain, individuals with knee OA may not be adequately aware of the importance of PA to their condition as few participants believed that they should avoid doing PA to avoid worsening their knees. Similarly, Holden et al. (2012) observed that knee OA individuals tended to perceive that exercise is unsafe for their condition. Beliefs and stereotypical images of physical inactivity associated with 'older' age also appeared to be prominent, as the participants who were aged between 50 and 56 years old believed that they are 'older' age, and culturally they are not considered as being able to do exercises. The cultural influence of ageing may indicate a lack of awareness and relate to the suggested perception that PA is for younger individuals only and for the purpose of enhancing physical appearance (Al-Hazzaa 2018).

Another cultural influence on PA was attributed to 'being female', which was found to be associated with additional gender-specific barriers. This finding agrees with the previous literature that found a high level of inactivity among Saudi females (Al-Eisa and Al-Sobayel 2012) when compared to male (Al-Hazzaa 2018). This low level of PA could be explained by the reported barriers, such as the conservative clothes, the absence of female school PA program, being worried about the community views of females practicing sport outdoors and a lack of social support. The only suggested solution to engage in PA for female was at the gyms, which the participants say are few in numbers and expensive. However, Alqahtani et al. (2020) found that despite the inadequate presence of female gyms, females are unwilling to participate in PA, which suggests that the other factors impact their decision to participate in PA more than the lack of gyms.

Previously, several barriers to PA such as lifestyle habits, lack of time, lack of facility and resources, urbanization, traffic, scorching weather and lack of social support have been reported (Al-Hazzaa 2018; Sharara et al. 2018; Alqahtani et al. 2020). The current findings agree with these previously reported barriers and highlight the importance of considering the weather as a primary reason for avoiding PA. Moreover, additional barriers such as previous negative experience with PA, lack of motivation, concerns with the privacy of the neighbourhood and inappropriate walking environment were identified in the current study and were also evident as barriers to PA in the Arab peninsula countries (Sharara et al. 2018).

11.1.2. PA analysis with Behaviour change wheel

The literature shows that physical activity in people with knee OA could be promoted with interventions that are designed based on behaviour change frameworks or theories such as the behaviour change wheel (BCW), which involves multilevel interventions that focus on targeting individuals, social environments, physical environments, and policies (Buchan et al. 2012). For example, a recent systematic review evaluated the effectiveness of physiotherapy-delivered behaviour change techniques for the promotion of PA for people with knee OA (Willett et al. 2019). The results show that behaviour change techniques such as goal setting, behavioural contract, self-monitoring, social support and rewards were effective in increasing the adherence to PA advice as part of physiotherapy treatment.

According to the BCW (Michie et al. 2014), there are three stages in designing behavioural interventions. First stage is to understand the behaviour through a behaviour analysis with capability, opportunity and motivation (COM-B model) domains. Hence, the identified barriers in the current study were allocated within the COM-B model, which resulted in identifying a wide range of factors/ barriers (Table 30).

The second stage of the BCW is to identify intervention options through selecting a number of interventions functions and policy category provided by the BCW (Michie et al. 2014). Therefore, for each identified barriers in the previous COM-B model, an intervention function and policy category were selected based on the relevance and identified as most likely to change the PA behaviour. Moreover, participants in the current study provided a number of suggestions to promote PA in the Saudi community, such as PA/ sports education for children and young adults, increasing the infrastructure resources such as building better walking environments, reducing gym prices, providing incentives or rewards and increasing the healthcare providers efforts to promote PA. Hence, these suggestions could be well situated and aimed as behavioural interventions in the views of the BCW (Michie et al. 2014). The following table lists the barriers and their intervention functions as selected from the BCW (Table 30).

Table 30 Barriers identified by study participants and BCW intervention options

<table>
<tr><th>COM-B model</th><th>Barriers identified by study participants</th><th>Intervention functions and policy category</th></tr>
<tr><td>Capability- Physical</td><td>Pain in individuals with knee OA</td><td rowspan="3">Education, Incentivisation and modelling</td></tr>
<tr><td rowspan="2">Capability- Psychological</td><td>Self-image</td></tr>
<tr><td>Fear of pain</td></tr>
<tr><td rowspan="4">Opportunity- Physical</td><td>Cities and environment are not built for walking</td><td rowspan="4">Environmental and social planning</td></tr>
<tr><td>The gym prices</td></tr>
<tr><td>Transports</td></tr>
<tr><td>Limited access to female-only gyms</td></tr>
<tr><td rowspan="3">Opportunity- Social</td><td>Lack of time</td><td rowspan="3">Education and Enablement</td></tr>
<tr><td>Lack of education for younger age</td></tr>
<tr><td>Lack of exercise partners</td></tr>
</table>

	Socially unacceptable, privacy issues	
	Lack of family support, especially for females	
	Perception and image of exercise in older age groups	
Motivation- Reflective	Laziness or ignorance	Education, Incentivisation and modelling
	Lack of motivation and interest	
Motivation- Automatic	Lack of awareness	
	Not part of lifestyle or culture	

The final stage of the BCW is to identify behaviour change technique and modes of delivery. This could be achieved by selecting the techniques deemed to be most effective and feasible in eliciting the desired behaviour change of promoting PA in individuals with knee OA. For example, the literature suggests a number of interventions techniques that could be used to promote PA in individuals with knee OA (Michie et al. 2014; Al-Hazzaa and AlMarzooqi 2018; Ojo et al. 2019), such as reconstructing the walking environment, goal setting, social support, instruction on how to perform PA, information about health consequences and other techniques. Willett et al. (2021) developed a theoretically informed physiotherapy intervention to optimise adherence to PA in people with knee OA. The authors proposed 26 behaviour change techniques, such as developing a PA routine during treatment and facilitating appropriate psychosocial support and access to resources for PA, which could be delivered during physiotherapy treatment and post-discharge (Willett et al. 2021). Therefore, the current findings may suggest the need for physiotherapists, physicians and policymakers to apply these identified behavioural intervention options to promote PA in people with knee OA in Saudi Arabia.

11.1.3. Efforts to promote PA

This study also explored the efforts to promote PA in the knee OA population and the Saudi community, which can be initiated by governmental authorities, individual organisations or personal efforts from healthcare providers (Al-hazzaa 2018). This study identified that there is some controversy regarding governmental efforts to promote PA in the community, which is acknowledged by some participants, while others argued that the government is not aware or may not doing enough to tackle the problem of physical inactivity. Although the Saudi government is building walking tracks, carrying out public health campaigns and has added sports teaching to female schools (Al-Hazzaa and AlMarzooqi 2018), some participants in the current study believed that these efforts were insufficient to promote PA, as campaigns are limited and walking tracks were inappropriately built. Moreover, a healthcare provider involved in campaigns to promote PA stated that the intended audience was younger people. Consequently, the current findings agree with previous studies that found current efforts to be insufficient (Al-Hazzaa and AlMarzooqi 2018; Rahman and Nahiduzzaman 2019; Alqahtani et al. 2020). Suggestions were made by the participants to increase PA in the community and knee OA individuals by improving the content and locations of campaigns and reaching wider audience demographics. In addition, the awareness of the importance of PA is believed to affect the younger individuals more than older individuals, who had a negative attitude towards the possibility to change. Interestingly, the participants reported that PA is a privilege for some people, and it should be rewarded in order to motivate the community and knee OA individuals to be more physically active. Hence, the suggested incentivisation intervention function from the BCW (Michie et al. 2014) could change the low PA level behaviour in knee OA individuals and the non-arthritic healthy community.

However, it should be acknowledged that there are governmental strategies to promote PA in the community, which may also be appropriate for people with knee OA. For example, the Saudi Ministry of Health website provides information on the importance of PA and methods to practice PA (Ministry of Health 2020), as well as a new strategy to promote PA in the community through campaigns and walking programs with the aim of attracting over a million participants every week in more than 80 locations that aim to have a healthier community (eye of Riyadh 2019). Furthermore, the Ministry of Health had a national strategy for diet and physical activity for 2014-2025, which aimed to improve health promotion by directing developmental efforts towards a continuous individual, community and country support (Ministry of Health 2014). The strategy is targeted at lowering the rate of individuals classified as overweight and obese from 66% to 40% and lowering the rate of people with low physical activity levels to 20%. Several organisations were involved in developing and implementing the strategy, such as the Ministry of Education, which aims to routinely measure weights and heights of students and define the norms and assessment of physical activity programs by allocating times for exercises during school days (Ministry of Health 2014). However, the strategy does not provide sufficient details on how to implement the PA recommendations by healthcare providers. Moreover, the success of such a strategy for reaching a wider audience has not been investigated yet.

Nevertheless, the findings of the current study suggest limited efforts in PA promotion may be in development, and the outcomes of such a strategy could be seen in future research. Clearly, the government is aware of the problem of PA despite the current study participants' claim. However, this study has shown barriers to PA, and campaigns may use this evidence to develop better strategies in the future in order to reach the majority of the Saudi population. Moreover, individuals with knee OA are encouraged to participate in PA despite the existing barriers as PA can improve their health condition and avoid the cycle of disuse (Celis-Morales et al. 2017), so it is important to address these barriers to improve the outcomes for these individuals.

11.2. Physiotherapists attitude and barriers towards clinical practice guidelines in Saudi Arabia.

11.2.1. Limited awareness of clinical practice guidelines

An important finding of the current study was the limited physiotherapists' awareness and adherence to evidence-based practice and CPGs, noting that the participated physiotherapists reported that they provided strengthening exercises, electrotherapy and patient education. This would suggest that the included physiotherapists may not read or follow the guidelines since they provided two out of three core treatments as they did not include aerobic exercises (Kolasinski et al. 2020). Consequently, the overall outcome and quality of care might be minimally affected (Spitaels et al. 2019; Holden et al. 2020). Moreover, several knee OA participants reported that they received limited education about PA as they were only advised to walk as part of the treatment plan. Nonetheless, physiotherapists expressed a wide range of responses in the knowledge of exercise prescription to enable PA, which may indicate the need to educate physiotherapists about improving PF components as a physical foundation for PA (Blair et al. 2001a; Vanhees et al. 2005; American College of Sports Medicine 2017). Moreover, knee pain was reported in knee OA individuals as a barrier to participate in PA. Hence, rehabilitation exercises may not be adhered to by knee OA individuals if physiotherapists are not fully aware of exercise prescription that aims to facilitate and enable PA of knee OA individuals (Willett et al. 2017; Onerup et al. 2019).

Nevertheless, the guidelines are not only about what is recommended but also what to avoid in terms of less effective approaches; hence, identifying that physiotherapists are still providing electrotherapy for knee OA suggests that there may be insufficient awareness of the guidelines. According to OARSI (Bannuru et al. 2019) and the American College of Rheumatology and Arthritis Foundation (Kolasinski et al. 2020) guidelines, TENS and ultrasound (electrotherapy modalities) are not recommended for knee OA due to the limited evidence base and the placebo effect. However, the use of such modalities could be linked to the knee OA individuals' request, as physiotherapists reported that knee OA individuals request these interventions as they believe they are effective for their case. However, it is the physiotherapists' responsibility is to educate individuals about the treatment options, which some physiotherapists in the current study did not adequately carry out.

Overall, physiotherapists are minimally adherent to the CPGs, as they do not effectively educated knee OA patients about PA and still provide non-evidence-based interventions. This finding agrees with the previous literature on the lack of guideline implementation and awareness in other countries. For instance, a study in Belgium by Spitaels et al. (2019) reported that physiotherapists provided only strengthening exercises for knee OA, while aerobic exercises and physical activity advice were not routinely provided. Similarly, the findings of Spitaels et al. (2017) show that physiotherapists in Belgium provided controversial interventions such as electrotherapy, massage and thermotherapy. Hence, this lack of guidelines adherence and awareness could be a global problem that may be attributed to the limitations of dissemination and barriers to the guidelines (Tittlemier et al. 2020).

11.2.2. Attitude and barriers to clinical practice guidelines

Our findings disagree in part with Alshehri et al. (2017), who reported a positive attitude and awareness towards evidence-based practice in Saudi Arabia by observing limited awareness of the guidelines and barriers to implementation; however, there is agreement on the identified barriers to the guidelines. For example, lack of support and encouragement, lack of interest and lack of time were reported as barriers to the guidelines in both studies. Furthermore, the current study also identified that physiotherapists believe that the guidelines are not adapted for or applicable to Saudi Arabian culture, suggesting the development of culture-specific recommendations. However, knee OA individuals have a similar clinical presentation globally, and the recommended interventions are applicable worldwide (Kolasinski et al. 2020), so the focus could need to be on enabling the application of the guidelines by physiotherapists.

Interestingly, the most reported barrier to guideline implementation was the lack of monitoring from the hospital administration regarding physiotherapists intervention. Hence, findings from the current study may suggest that guideline implementation would only increase if there were orders from the hospital administration. Moreover, this may indicate the need for behaviour change approaches that could increase the physiotherapists' awareness of evidence-based practice (Willett et al. 2019). However, continuing professional development in Saudi Arabia is mainly provided by the Saudi Physical Therapy Association, which has been providing resources such as lectures and workshops for physiotherapists aiming to increase the physiotherapists' awareness and adherence to clinical practice guidelines (Saudi Physical Therapy Association 2021). Therefore, the Saudi Physical Therapy Association may consider the identified barriers to guideline implementation to improve physiotherapists adherence and awareness towards evidence-based practice.

11.2.3. Limitations of clinical practice guidelines

This limited awareness and implementation of guidelines could be due to the reported limitations in the structure of the CPGs since most of them do not consider the applicability and dissemination of the guidelines into clinical practice. Ferreira de Meneses et al. (2016) outlines three main barriers to guidelines implementation, namely: literature limitation, external limitation and guidelines limitation. First, a limitation in the literature such as inadequate evidence for individuals with comorbidities, lack of evidence for targeted joints, and contradictory information in some guidelines. Second, several external limitations were presented by Ferreira de Meneses et al. (2016) that contribute to the lack of uptake of the guidelines. For example, the barriers on the individual level are; lack of GP time to see individuals, lack of skills and resistance of individuals to change behaviour. The barriers at an organisational level were problems in the referral process, an inadequate model of care and a weak multidisciplinary system. Lastly, the guidelines-specific limitations are; the lack of a standardised methodology in guidelines development resulting in variations in recommendations, inadequate description of the recommendations, difficulty in applying recommendations to individuals with multiple conditions and different phenotypes.

Ferreira de Meneses et al. (2016) argue that guidelines are disease-specific rather than targeted to individuals. However, changing the aim of the recommendations from disease-specific to patient-specific is not encouraged since individuals may share the same disease and symptoms, but they might have different comorbidities and physical presentations. Therefore, developing patient-specific guidelines is challenging, and aiming to create a guideline for each phenotype is not necessarily appropriate. Instead, clinical algorithms such as OARSI (Bannuru et al. 2019) and the American College of Rheumatology and Arthritis Foundation (Kolasinski et al. 2020) are encouraged to develop. Clinical algorithms propose step-wise pathways for dealing with different individuals' symptoms of the same disease while maintaining the core treatments (Bannuru et al. 2019; Bruyère et al. 2019). The guidelines are recommended as a source for evidence-based guidelines for clinical practice; however, they are still underdeveloped, and they need to consider the stated limitations, which may explain why they are not sufficiently followed.

11.3. Participants perspectives on healthcare delivery for individuals with knee osteoarthritis in Saudi Arabia.

The current study shows that the healthcare journey was mainly dependent on the resources, patient and physician decisions. Although there are a variety of healthcare professionals involved in the knee OA patient journey, it was found that there is an absence of multidisciplinary teamwork, limited professional communication and acknowledgement of interprofessional roles and barriers to professional autonomy, especially with physiotherapy. Moreover, most of the OA individuals reported a poor experience during their healthcare journey that could be due to a non-efficient healthcare system, referral delays and poor quality of service in Saudi Arabia. In particular, there appears to be a problem in accessing physiotherapy services caused by a lack of physiotherapy clinics, no direct access to physiotherapy and a delayed referral system to physiotherapy. Furthermore, some physicians and OA individuals expressed a limited awareness of the role of physiotherapy in the treatment of knee OA. Regarding treatments, medical injections were reported as effective, whereas physiotherapy intervention effectiveness was varied.

11.3.1. Access to physiotherapy

This study was the first to explore the healthcare organisation and physiotherapy access for individuals with knee OA in Saudi Arabia. The findings may suggest a gap in the literature with regards to the current healthcare system for individuals with knee OA in Saudi Arabia and may serve as a basic description of the healthcare system for accessing physiotherapy service for individuals with knee OA. Nevertheless, in some countries such as Australia and the United Kingdom, the patient journey for knee OA individuals typically starts at the primary healthcare centres with the general physicians as a central care coordinator (Victorian Musculoskeletal Clinical Leadership Group 2018; Simonse et al. 2019). However, in Saudi Arabia, people have the freedom to directly access the primary healthcare centres with family physicians who can refer to an orthopaedic specialist, or they can directly access the orthopaedic specialist as the only pathway to access physiotherapy service. This referral system is different from the United Kingdom (Button et al. 2019; Simonse et al. 2019) that allows general physicians in primary healthcare centres to refer knee OA individuals to physiotherapy.

The current findings show that there is currently no direct access to physiotherapy in Saudi Arabia as physicians are the only pathway to access physiotherapy services, and they may refer knee OA individuals to physiotherapy immediately or after trying alternative interventions, which may cause delays in physiotherapy service access (Alshehri et al. 2018). Furthermore, physiotherapists and physicians participants reported that physicians might write physiotherapists treatment plan within the referral reports. Hence, physiotherapists were concerned about their autonomy and their ability to apply evidence-based interventions. However, this could be explained by the findings of Alshehri et al.

(2018), which shows that physicians believed that physiotherapists lack the skills and knowledge to assess and treat patients.

For knee OA individuals, the choice of preferred healthcare access could indicate their involvement in decision-making, ownership of their health and health locus of control (Marton et al. 2021). However, the decision to seek consultation from an orthopaedic surgeon rather than a family physician could be attributed to the current findings of an inefficient healthcare system and delays in referrals. For instance, the findings show that if individuals were seen at the primary healthcare centres, they would eventually be referred to orthopaedic surgeons who will repeat the same tests and interventions while offering more advanced treatments and referrals to physiotherapy. Consequently, the findings show that individuals may take shortcuts by directly accessing orthopaedic surgeons and taking advantage of the lack of a coordinated healthcare system.

11.3.2. Inefficient healthcare system

11.3.2.1. Increased workload

The direct access of knee OA individuals to the orthopaedic clinic was reported to be a limitation in the system as it causes an increase in the workload on the orthopaedic surgeons and may lead to reduced quality of care. The increase in workload and the perceived inefficiencies in the healthcare system was reported to lead to a delay in service access, inability to provide guidelines-based interventions such as PA education and delay in physiotherapy referrals. Previous evidence shows that heavy workload may lead to burnout of health professionals, reduced quality of care (Humphries et al. 2014) and reduced concern for individuals (Abushaikha and Saca-Hazboun 2009). Hence, the high workload has been reported in this study by physicians and physiotherapists as one of the reasons for reduced adherence to the guidelines and an inability to educate individuals about disease or PA. Consequently, this may explain the perceived poor knee OA individuals' experience in the healthcare journey and may be considered as a barrier to physiotherapists guidelines implementation that may affect PA education for people with knee OA.

11.3.2.2. Limited multidisciplinary teamwork

The perceived inefficiencies in the healthcare system could also be linked to the reported limited multidisciplinary teamwork for managing knee OA. Previous studies show that the management of knee OA individuals are guided by the holistic approach of multiple professionals that cover different aspects of the patient's life (Marszalek et al. 2017; Victorian Musculoskeletal Clinical Leadership Group 2018; Bannuru et al. 2019). However, the findings of the current study suggest limited team planning and communication as each healthcare provider may work independently from others, with only referral reports as a source of communication. Hence, the quality of care for individuals with knee OA might be reduced by repetition of interventions and delay in physiotherapy referrals, which may also explain the reported poor experience.

11.3.2.3. Repeated and varied interventions

Another important finding was the inefficient system with regards to the treatment for knee OA. To elaborate, the current findings showed that medical interventions are offered in a varied pattern based on the physician's judgment; some would have injections first, while others are treated with medications only. Some are referred to physiotherapy immediately, while others are referred after trying alternative interventions. Thus, the healthcare service may not consistently align with the individuals' needs or with the best evidence for adequate care, which may lead to diverse quality of care from one clinic to another (Spitaels et al. 2019), and knee OA individuals may be confused about the most appropriate first-line of treatment (Croker et al. 2013). Consequently, the findings show that knee OA individuals may request or refuse specific interventions, which may not necessarily indicate limited awareness but instead could suggest confusion, lack of confidence in the physician's decision or other factors that require further exploration (Croker et al. 2013; Kim et al. 2018).

According to the literature, knee OA can be diagnosed clinically without the need for diagnostic imaging (Arden et al. 2018a; Victorian Musculoskeletal Clinical Leadership Group 2018). However, this study's findings indicate that most of the individuals presenting to primary healthcare centres or the orthopaedic clinic are diagnosed with imaging tests, sometimes undertaken at both clinics. This may be considered as an avoidable overuse of resources, which can save the individuals' time, costs of imaging and unnecessary exposure to radiation. Moreover, the use of injections as the first line of treatment was not recommended in the CPGs for managing mild to moderate knee OA (Hochberg et al. 2012; Nelson et al. 2014; Kolasinski et al. 2020), which would also suggest an inappropriate use of resources.

11.4. Clinical implications

There are several barriers identified in this study, which are essential to consider in order to promote PA in the knee OA individuals and Saudi population. The behaviour analysis with the BCW shows a number of barriers such as knee pain, self-image and fear of pain in individuals with knee OA, laziness and lack of awareness and interest in PA. In addition to barriers in social and physical opportunities such as lack of time, high gym prices, transport, lack of social support and inefficient walking environment. Therefore, policymakers in Saudi Arabia could consider the identified behavioural interventions functions and policy categories such as education, environmental planning, incentivisation, and modelling, which may change PA behaviour in knee OA individuals.

This study also shows that there might be a gender difference in the barriers and attitude towards PA. This could suggest that in females, social barriers are highly significant, and it is essential to consider the enablement and resources in order to promote PA (Rosselli et al. 2020; Cowley et al. 2021). The current findings showed that the promotion of PA within the healthcare system is limited, and it is essentially recommended to include PA education for knee OA individuals by each healthcare provider during the patient journey in seeking healthcare (Coste et al. 2020; Holden et al. 2020). However, there are several limitations in healthcare practice found in this study, such as inefficient healthcare system, referral delays and personal judgment. These identified limitations highlight potential recommendations to the Ministry of Health to embed multidisciplinary teamwork in the management of knee OA.

The study showed limited physiotherapists adherence and barriers to implementation of clinical practice guidelines such as lack of time, lack of support and encouragement and lack of interest. These identified barriers to guidelines would indicate the need for policymakers within the Ministry of Health to create strategies to improve physiotherapists awareness about evidence-based practice. This would improve the physiotherapists' skills in understanding and applying evidence-based practice by allowing them to critically review the evidence and apply it to match patient and service needs (Stander et al. 2018; Lehane et al. 2019). Moreover, physiotherapists knowledge of exercise prescription that aims to enable PA showed a wide range of responses. Although it was not the scope/ limit of the current study, it may suggest a gap in clinical practice, indicating the need to educate physiotherapists about PA enablement (Clark et al. 2017). This could be achieved by improving physiotherapists awareness towards including PF components as the physical foundation for PA (Blair et al. 2001a; Vanhees et al. 2005; American College of Sports Medicine 2017) and an individualized treatment plan that focuses on the patients' capabilities and needs (Bannuru et al. 2019).

11.5. Limitations of phase 2

Phase 2 of this study has several limitations. Telephone interviews may limit the ability to control the interview environment, they do not allow for social cues to be observed, and the shorter interview duration may reduce the depth and richness of data. Hence, an alternative interview method such as conducting face-to-face interviews would avoid these limitations, which may result in richer and more in-depth findings (Vogl 2013; Taylor et al. 2016). Furthermore, this study aimed to explore the participants' perspectives on the opportunities and barriers to physical activity, which aimed to include policymakers. However, the researcher was not able to reach policymakers who are key influencers in PA and healthcare service. Therefore, the current PA promotion strategies and policymakers understanding of the problem of low PA levels was not sufficiently explored. Additionally, healthcare providers may have been reluctant to expose sub-optimal practice in their organisation as they may uphold their hospitals and the profession's reputation.

11.6. Recommendations from phase 2

There are a number of recommendations and benefits from the findings of this research to the clinical practice and future studies. First, the identified barriers and interventions with the BCW could suggest the need for strategies based on behaviour change frameworks or theories in order to promote PA in individuals with knee OA. The authorities in Saudi Arabia may consider the low physical activity levels as one of the national goals that need to be improved that could be involved in the 2030 vision (Kingdom of Saudi Arabia 2030 Vision 2016) to improve the quality of life and PA encouragement. There could be a collaboration between the ministries to promote PA in schools and workplaces, which could be in the form of rewards such as school marks/ grades or physical rewards.

It is recommended to improve the awareness of physiotherapists to the evidence-based practice guidelines by providing development opportunities for physiotherapists such as journal clubs, in-service training sessions, sharing case studies and lecturing. Moreover, to avoid the several limitations in the healthcare system identified in this study, the Ministry of Health is recommended to create an evidence-based system, recognized and followed within their hospitals such as the Victorian healthcare system (Victorian Musculoskeletal Clinical Leadership Group 2018) and United Kingdom healthcare system (Button et al. 2019). This would improve the healthcare service by including a multidisciplinary team in the management of knee OA and allow easier access and referrals to physiotherapy services.

12. Chapter 12: Conclusion of phase 2

The second phase of this study was a qualitative study using semi-structured interviews to explore participants perspectives on the opportunities and barriers to physical activity in Saudi Arabia for individuals with knee OA. In addition, physiotherapists attitudes and barriers towards clinical practice guidelines in Saudi Arabia were explored. The participants included physicians, physiotherapists, individuals with knee OA, non-arthritic healthy participants, a personal trainer and a schoolteacher. Thematic analysis was used to analyse the interview transcripts, which resulted in the development of four main themes: Organization of Care of Individuals with Knee OA, Physiotherapy Service and International Guidelines Practice for Knee OA, The Culture of Physical Inactivity, and Participants Views of The Healthcare System for Individuals with Knee OA.

The main findings of phase 2 showed that there are several barriers to PA in individuals with knee OA, with limited efforts to promote PA in people with knee OA. In addition, healthcare providers believed that it is the responsibility of physiotherapists to educate the patients as well as the population about the benefits of PA, while other participants maintained that it is the responsibility of the whole community. The participants, as well as the BCW analysis, suggested a number of interventions that could promote PA in knee OA individuals, such as building a better walking environment, reducing gym prices, providing incentives or rewards and increasing the healthcare providers efforts to promote PA.

Additionally, the study showed limited physiotherapist adherence and barriers to implementation of clinical practice guidelines such as lack of time, lack of support and encouragement and lack of interest. The study also addressed several limitations in the individuals’ journey for seeking healthcare, such as inefficiencies in the healthcare system, delays to accessing healthcare and physiotherapy and low quality of service, which may have been a reflection of the physicians' limited awareness of the role of physiotherapy in the treatment of knee OA. Hence, the overall healthcare journey was perceived as a poor experience.

13. Chapter 13: Integration of mixed methods

The integration of mixed methods data was reported to occur concurrently or sequentially, based on the research design and aim, which may occur through narrative reports, data transformation or comparison (Doyle et al. 2009; Creswell and Plano Clark 2017). In the current study, quantitative and qualitative data were obtained independently during data collection, and the analysis followed a sequential explanatory research design as well as the pragmatism paradigm, which guided the two phases of this study. One possible data integration method is the merging of results or transforming qualitative findings into quantitative ones (Terell 2012), which was not carried out in the current study since the two phases are independent and data reduction was not needed. However, the integration of the quantitative and qualitative phases was carried out at the final stage of the research during interpretation (Creswell and Plano Clark 2017). The quantitative and qualitative results were combined together in order to integrate the findings and generate a comprehensive understanding of the research question and discuss how the qualitative phase was able to explain the quantitative results (Ivankova et al. 2006).

Creswell and Plano Clark (2017) described the representation of the integrated mixed methods results in the sequential design through a joint display. The aim of this method is to present the link between the two phases and to show how qualitative findings enhanced our understanding of the quantitative results. This was presented in Table 31, which outlines the links between phase 1 and phase 2.

Table 31 Joint display of integration of mixed methods results

Results from phase 1 needed to be explained	Explanations found from phase 2	Clinical implications
No significant differences between non-arthritic healthy individuals and knee OA, in terms of PA level as both groups, were considered physically low active	• There are several barriers that led to the state of low PA levels, especially with females. • PA is not part of the lifestyle or culture. • There are limited healthcare providers efforts to promote PA in knee OA individuals • The participants and BCW analysis suggested several interventions to promote PA	There is a need to consider the identified behavioural interventions such as education, environmental planning, incentivisation and modelling in order to promote PA for knee OA individuals, which may also apply to the wider population
Both groups were overweight		
Barriers and facilitators to PA needed more objective and in-depth exploration		
Knee OA individuals are recommended by clinical practice guidelines to receive PA advice as part of the treatment plan. However, the results of phase 1 showed low physical activity levels in knee OA individuals. Hence, there was a need to explore the physiotherapists' attitude towards the guidelines to understand the implementation barriers in Saudi Arabia.	• Most physiotherapists have inadequately adhered to clinical practice guidelines due to several barriers in the form of practical or personal barriers. • The core treatments were strengthening exercise and electrotherapy. • A small number of physiotherapists provided PA advice. • The changes in guidelines adherence behaviour were linked to the existence of instructions from the	There is a need for policymakers within the Ministry of Health to create strategies to increase the awareness of physiotherapists to evidence-based practice and clinical practice guidelines

	hospital administrators to follow the guidelines.	
There was a need to explore the healthcare providers perspective on the barriers and facilitators to PA within the healthcare system in Saudi Arabia for people with knee OA, which had not been previously investigated before	• There are no coordinated multidisciplinary teams that work together or an agreed system for the management of knee OA. • The patient journey pathways and treatments choices were mainly dependent on the available resources, individuals with knee OA and physician decisions.	The Ministry of Health is recommended to create a system that involves a multidisciplinary team in managing knee OA.
	• The management of knee OA cases is based mainly on the experience and preference of physiotherapists and the individuals' acceptance of the intervention.	

Beginning with phase 1 results that needed to be explained and explored in-depth with the second phase. Firstly, there was no statistically significant difference in PA between non-arthritic healthy individuals and knee OA participants, which was unexpected since the literature shows that knee OA is associated with physical inactivity due to pain and muscle weakness (Felson et al. 2007), and individuals with knee OA have been shown to be less physically active compared to non-arthritic healthy individuals (Moseng et al. 2014; Herbolsheimer et al. 2016; Vårbakken et al. 2019a). Therefore, knee OA individuals may have more physical barriers to PA compared to non-arthritic healthy subjects, which may explain their low physical activity levels. However, our results showed that both groups were considered to have low physical activity levels, which may suggest that despite the physical barriers, there could be cultural or environmental barriers that needed to be identified in order to effectively suggest recommendations to promote PA in the knee OA population in Saudi Arabia. Moreover, our results showed that the majority of participants in both groups were also considered overweight/ obese, which may agree with the results of physical inactivity. However, obesity was established to be one of the most significant risk factors for developing knee OA (Palazzo et al. 2016), suggesting that even the comparator group may be susceptible to the disease if obesity and physical inactivity were not challenged.

Finally, in phase 1 results from the barriers and facilitators to PA questionnaires demonstrated barriers to PA on an individual and environmental levels, but no social barriers were identified, in conflict with the previous literature (Dobson et al. 2016b; Al-Hazzaa 2018). The previous results may indicate that PA is a problem in both knee OA and the non-arthritic healthy community in Saudi Arabia, and it must be explained and explored with more in-depth research that aimed to identify the attitude and barriers to PA. Moreover, knee OA individuals were recommended by clinical practice guidelines to receive PA advice as core treatments (Kolasinski et al. 2020). However, finding that knee OA participants in phase 1 were considered with low physical activity levels suggested a need to explore the physiotherapists' attitude and barriers towards guidelines and evidence-based practice for individuals with knee OA in Saudi Arabia.

The thematic analysis findings of phase 2 explained phase 1 results. These qualitative findings were able to explain the quantitative findings in terms of lack of physical activity in both groups and identified additional PA barriers. Particularly the key findings of theme 3, 'The Culture of Physical Inactivity, demonstrated the presence of several barriers that led to the state of low physical activity in Saudi Arabia, especially with females, and PA was not part of the lifestyle or culture. The identified barriers were mostly physical, personal, social and environmental barriers. Moreover, there are limited healthcare provider efforts to promote PA for people with knee OA. Acknowledging the importance of PA to the knee OA population hence, PA promotion for knee OA may not be successful without national strategies that aim to improve the PA of the Saudi population underpinned by behaviour change theories.

The organisation of care for knee OA individuals in Saudi Arabia has not been investigated before. The findings from themes 1 and 2 (‘Organization of Care for Individuals with Knee OA’ and ‘Physiotherapy Service and International Guidelines Practice for Knee OA’) show that the management of knee OA cases is based mainly on the experience and preference of physiotherapists and the individuals' acceptance of the intervention. The core physiotherapy treatments were strengthening exercises and electrotherapy, along with limited PA advice. Moreover, physiotherapists knowledge of exercise prescription that aims to enable PA showed a wide range of responses, which may suggest a gap in clinical practice, indicating the need to educate physiotherapists about PA enablement through the improvement of PF components (Blair et al. 2001b; American College of Sports Medicine 2017).

Consequently, it may suggest that physiotherapists do not adhere to the CPGs recommendation to treat knee OA (National Institute for Health and Clinical Excellence 2014; Bannuru et al. 2019). This was also confirmed by identifying that most of the physiotherapists interviewed were minimally following the treatment guidelines due to several barriers in the form of practical or personal barriers such as lack of interest, lack of time and motivation, and lack of instructions from hospital administrations. Our results agree with previous studies on physiotherapists adherence to CPGs (Jansen et al. 2010; Ingelsrud et al. 2019; Spitaels et al. 2019). Thus, CPGs dissemination and applicability is challenging, and strategies for increasing adherence to these recommendations should consider the clinical application in addition to the evidence-based interventions.

Regarding the lack of research exploring the organisation of care for individuals with knee OA in Saudi Arabia, phase 2 findings of this study indicate that there are no or few coordinated multidisciplinary teams that work together or have an agreed and established system for the management of knee OA. The patient journey pathways and treatments choices were mainly dependent on the available resources, individual’s preferences and presentations of knee OA and physician decisions.

13.1. Recommendations for future research

There is a tendency for low physical activity and a high proportion of participants to be considered overweight/ obese in both knee OA and non-arthritic healthy individuals in this sample, which appears to be indicative of the wider Saudi Arabian population. Phase 2 of the research has uncovered the complexities of implementing a successful behavioural intervention. Therefore, targeted behavioural interventions such as modelling, incentives and environmental planning at a population level may be warranted and would require further evaluation for their effectiveness. Future studies are recommended to measure the difference in PA between males and females and identify the specific gender barriers to participating in PA in Saudi Arabia. This would provide policymakers in Saudi Arabia with evidence-based information that could be used to promote PA in females.

There is a need for more studies evaluating the organisation of care for knee OA in Saudi Arabia to explore the different systems and decision-making processes and how these could be optimised for patient benefit. There is also a need for studies that explore the healthcare providers awareness towards physiotherapy and explore physiotherapists autonomy and evidence-based skills in the management of knee OA. Finally, there is a gap in clinical practice guidelines recommendations, which lack details of exercise prescription for people with knee OA. Hence, they are encouraged to further develop their recommendations by including exercise prescription details following the FITT principle.

14. Chapter 14: Conclusion of the thesis

This project has two sequential phases. In phase 1, the aim was to evaluate differences in physical fitness components and physical activity levels in people with knee osteoarthritis compared to non-arthritic healthy individuals in Saudi Arabia. The main findings from phase 1 showed that individuals with knee OA have lower physical fitness components such as aerobic capacity, muscular fitness, flexibility and balance than comparator group. However, body composition was not statistically significantly different between groups, as both groups were identified to be primarily overweight/ obese. The study found no statistically significant difference in PA levels between knee OA and comparator groups, as both groups were considered to have low PA levels. Furthermore, the barriers and facilitators questionnaire showed that PA was limited by a number of barriers in both groups, suggesting that wider cultural factors may be contributory factors or cause. Hence, the results of phase 1 indicated the need for an in-depth explanation and exploration of the opportunities and barriers to PA in Saudi Arabia for individuals both with and without knee OA. Moreover, knee OA individuals were recommended by clinical practice guidelines to receive PA advice as core treatments (Kolasinski et al. 2020). However, finding that knee OA participants in phase 1 were considered with low physical activity levels suggested a need to explore the physiotherapists' attitude and barriers towards guidelines and evidence-based practice for individuals with knee OA in Saudi Arabia. This could be achieved by interviewing individuals who might be affected by the changes in PA or those who influence the healthcare system and policymakers in Saudi Arabia.

Consequently, the second phase of this study was a qualitative design in the form of semi-structured interviews. The participants included physicians, physiotherapists, individuals with knee OA, non-arthritic healthy participants, personal trainer and schoolteacher. The main findings of phase 2 showed that there are several barriers to PA, with limited healthcare providers efforts to promote PA in knee OA individuals and the non-arthritic healthy population. The BCW analysis and the participants suggested several recommendations in order to promote PA in knee OA individuals, such as rewards, better walking environment and school education, easier females' access to transportation and better gym prices. The study also found that most of the physiotherapists expressed limited adherence to treatment guidelines due to practical or personal barriers, and physicians expressed limited awareness of the role of physiotherapy in the treatment of knee OA. Several limitations in the individuals' journey for seeking healthcare were addressed, such as the perceived inefficiencies in the healthcare system, delays, low quality of service, which may have led to the perceived poor experience for individuals with knee OA.

Overall, the comprehensive assessment of PF in knee OA sample from Saudi Arabia indicated that the OA population have low aerobic capacity, muscle fitness, balance and flexibility compared to non-arthritic healthy individuals. This may suggest the need to consider the PF components such as flexibility, balance, aerobic, strength and weight loss exercises in the treatment plan. Moreover, this study findings suggest that policymakers in Saudi Arabia could consider the identified PA barriers and the BCW interventions that would improve the promotion of PA in knee OA individuals and the community. Furthermore, this study highlights the need to improve the healthcare service for individuals with knee OA via increasing physiotherapists autonomy and awareness to evidence-based practice and involvement of multidisciplinary teamwork.

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16. Appendices

16.1. Appendix A: Recruitment Poster

مطلوب متطوعين للمشاركة في بحث

هل تعاني من خشونة في الركبة ؟

هل تريد معرفة لياقتك وقوتك البدنية واستعدادك للتمرين قبل البدء في جلسات العلاج الطبيعي ؟

بالتعاون مع جامعة كاردف ببريطانيا، وجامعة ام القرى بمكة. أنت مدعو للمشاركة في دراسة بعنوان (مستويات اللياقة البدنية والنشاط البدني، في الأفراد الذين يعانون من مرض خشونة مفصل الركبة). سيتم قياس استهلاك الطاقة الحركية الخاصة بك، قوة ومرونة العضلات، التوازن و قدرة القلب والجهاز التنفسي على تحمل التمارين.

- العمر المطلوب: 45 سنة فما فوق
- مع أو بدون مرض خشونة مفصل الركبة
- مع أو بدون آلام فى الركبة

المدة: ساعة

الموقع: جامعة ام القرى، كلية العلوم الطبية التطبيقية، قسم العلاج الطبيعي

للمشاركة والاستفسار الاتصال على/ د. مؤيد سبحي

16.2. Appendix B: Physical Activity Readiness Questionnaire

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ______________________________

SIGNATURE ______________________________ DATE ______________________________

SIGNATURE OF PARENT ______________________________ WITNESS ______________________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

CSEP | SCPE

استبيان استعداد النشاط البدني (PAR-Q)

(استبيان للأشخاص الذين تتراوح أعمارهم بين ١٥ و٦٩ عاما)

النشاط البدني المنتظم هو متعة وصحة، ويدأ المزيد من الناس على نحو متزايد بأن يصبحوا أكثر نشاطا كل يوم. أن تكون أكثر نشاطا آمن جدا بالنسبة لمعظم الأشخاص. ولكن، يجب على بعض الأشخاص التحقق مع طبيبهم قبل أن يبدأ في زيادة النشاط البدني.
إذا كنت تخطط لتصبح أكثر نشاطا، ابدأ بالإجابة على الأسئلة السبعة في المربع أدناه. إذا كان عمرك يتراوح ما بين ١٥ و٦٩ عاما، فإن الاستبيان سوف يقول لك ما إذا كان يجب عليك التحقق مع الطبيب قبل البدء. إذا كان عمرك يزيد عن 69 عاما، ولم تكن معتادا على أن تكون نشطا جدا، تحقق مع طبيبك.
الحس السليم وإدراكك بحالتك الصحية هو أفضل دليل عند الإجابة على هذه الأسئلة. يرجى قراءة الأسئلة بعناية والإجابة على كل واحد بصراحة. فضلا اختر نعم أو لا

١. هل سبق لك أن قال طبيبك أن لديك حالة في القلب وأنك يجب أن تفعل فقط النشاط البدني الموصى بها من قبل الطبيب؟	نعم ○ لا ○
٢. هل تشعر بالألم في صدرك عند ممارسة النشاط البدني؟	نعم ○ لا ○
٣. في الشهر الماضي، هل شعرت بألم في الصدر عندما كنت **لا** تفعل النشاط البدني؟	نعم ○ لا ○
٤. هل تفقد توازنك بسبب الدوخة أو هل فقدت الوعي في أي وقت مضى؟	نعم ○ لا ○
٥. هل لديك مشكلة العظام أو المفاصل (على سبيل المثال، الظهر، الركبة أو الورك) التي يمكن أن تزداد سوءا من خلال تغيير في النشاط البدني الخاص بك؟	نعم ○ لا ○
٦. هل يصف لك طبيبك حاليا أدوية مثل حبوب الماء لعلاج ضغط الدم أو مشكلة في القلب؟	نعم ○ لا ○
٧. هل تعرف أي سبب آخر لماذا لا يجب أن تزيد نشاطك البدني؟	نعم ○ لا ○

اذا أجبت ب (نعم) على أي من الأسئلة

تحدث مع طبيبك عن طريق الهاتف أو شخصيا قبل أن تبدأ بزيادة نشاطك البدني أو قبل أن يكون لديك اختبار لتقييم اللياقة البدنية. أخبر طبيبك عن الاستبيان وعن الأسئلة التي أجبت عليها بنعم.

- قد تكون قادرا على القيام بأي نشاط تريده - ما دامت تبدأ ببطء وتتطور تدريجيا.
- أو قد تحتاج إلى تقييد أنشطتك إلى تلك التي هي آمنة بالنسبة لك.
- تحدث مع طبيبك عن أنواع الأنشطة التي ترغب في المشاركة فيها واتبع نصائحه.

اذا أجبت ب (لا) على جميع الأسئلة

إذا اجبت ب (لا) على جميع الأسئلة وبصراحة. يمكنك ان تكون متأكدا بشكل معقول انه يمكنك:

- ان تبدأ تدريجيا وبشكل امن بزيادة نشاطك البدني
- المشاركة في برامج تقييم اللياقة البدنية، التي تعتبر وسيلة ممتازة لتحديد اللياقة البدنية الحالية، وبذلك يمكنك التخطيط لأفضل طريقة لك للعيش بنشاط ولياقة.
- ينصح بشدة بقياس ضغط الدم باستمرار، إذا كان ضغط الدم أكثر من ١٤٤/٩٤، تحدث مع طبيبك قبل زيادة نشاطك البدني والبدء بالتمارين.

تستطيع تأجيل زيادة نشاطك البدني والبدء بالتمارين:

- إذا كنت لا تشعر بشكل جيد بسبب مرض مؤقت مثل البرد أو الحمى - انتظر حتى تشعر أنك أفضل
- إذا كنت حاملا - تحدثي مع طبيبك قبل البدء في زيادة نشاطك البدني والبدء بالتمرين.

"لقد قرأت وفهمت واكملت هذا الاستبيان، وقد تم الرد على جميع الأسئلة برضاي الكامل"

الاسم: ________________ التاريخ: ___/___/___

التوقيع: ________________ رقم المعرف: __________

16.3. Appendix C: Knee Osteoarthritis Outcome Score (KOOS)

KOOS KNEE SURVEY

Today's date: _____/______/______ Date of birth: _____/______/______

Name: ____

INSTRUCTIONS: This survey asks for your view about your knee. This information will help us keep track of how you feel about your knee and how well you are able to perform your usual activities.
Answer every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can.

Symptoms
These questions should be answered thinking of your knee symptoms during the **last week**.

S1. Do you have swelling in your knee?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S2. Do you feel grinding, hear clicking or any other type of noise when your knee moves?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S3. Does your knee catch or hang up when moving?

Never	Rarely	Sometimes	Often	Always
☐	☐	☐	☐	☐

S4. Can you straighten your knee fully?

Always	Often	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

S5. Can you bend your knee fully?

Always	Often	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

Stiffness
The following questions concern the amount of joint stiffness you have experienced during the **last week** in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your knee joint.

S6. How severe is your knee joint stiffness after first wakening in the morning?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

S7. How severe is your knee stiffness after sitting, lying or resting **later in the day**?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Pain

P1. How often do you experience knee pain?

Never	Monthly	Weekly	Daily	Always
☐	☐	☐	☐	☐

What amount of knee pain have you experienced the **last week** during the following activities?

P2. Twisting/pivoting on your knee

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P3. Straightening knee fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P4. Bending knee fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P5. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P6. Going up or down stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P7. At night while in bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P8. Sitting or lying

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P9. Standing upright

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, daily living

The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A1. Descending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A2. Ascending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A3. Rising from sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A4. Standing

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A5. Bending to floor/pick up an object

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A6. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A7. Getting in/out of car

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A8. Going shopping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A9. Putting on socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A10. Rising from bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A11. Taking off socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A12. Lying in bed (turning over, maintaining knee position)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A13. Getting in/out of bath

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A14. Sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A15. Getting on/off toilet

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A16. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A17. Light domestic duties (cooking, dusting, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, sports and recreational activities

The following questions concern your physical function when being active on a higher level. The questions should be answered thinking of what degree of difficulty you have experienced during the **last week** due to your knee.

SP1. Squatting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP2. Running

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP3. Jumping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP4. Twisting/pivoting on your injured knee

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP5. Kneeling

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Quality of Life

Q1. How often are you aware of your knee problem?

Never	Monthly	Weekly	Daily	Constantly
☐	☐	☐	☐	☐

Q2. Have you modified your life style to avoid potentially damaging activities to your knee?

Not at all	Mildly	Moderately	Severely	Totally
☐	☐	☐	☐	☐

Q3. How much are you troubled with lack of confidence in your knee?

Not at all	Mildly	Moderately	Severely	Extremely
☐	☐	☐	☐	☐

Q4. In general, how much difficulty do you have with your knee?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Thank you very much for completing all the questions in this questionnaire.

استبانة الإلتهاب المفصلي العظمي وإصابات الركبة

تاريخ اليوم: ____/____/____ تاريخ الميلاد: ____/____/____

الاسم: ______________________________

التعليمات: هذه الاستبانة صممت لمعرفة رأيك حول ركبتك. معلومات هذه الاستبانة سوف تساعدنا في معرفة شعورك بركبتك وكيف ستكون قادراً على أداء نشاطاتك الاعتيادية.

أجب عن كل سؤال بوضع علامة في المربع المناسب. اختر مربع واحد فقط لكل سؤال. إذا كنت غير متأكد من الإجابة اختر أقرب اجابة مناسبة.

الأعراض:

يجب أن تكون الإجابة على هذه الأسئلة بناء على أعراض ركبتك خلال **الأسبوع الماضي**

S1 هل يوجد تورم في ركبتك؟

أبداً	نادراً	أحياناً	غالباً	دائماً
□	□	□	□	□

S2 هل تشعر بصرير أو تسمع طقطقه أو أي صوت في ركبتك عند تحريك الركبة؟

أبداً	نادراً	أحياناً	غالباً	دائماً
□	□	□	□	□

S3 هل ركبتك تتصلب عند الحركة؟

أبداً	نادراً	أحياناً	غالباً	دائماً
□	□	□	□	□

S4 هل تستطيع مدّ ركبتك بشكل كامل؟

دائماً	غالباً	أحياناً	نادراً	أبداً
□	□	□	□	□

S5 هل تستطيع ثني ركبتك بشكل كامل؟

دائماً	غالباً	أحياناً	نادراً	أبداً
□	□	□	□	□

التصلب: الأسئلة التالية تتعلق **بمقدار تصلب** المفصل الذي عانيت منه **الأسبوع الماضي** في ركبتك.
التصلب هو الإحساس بتقييد أو بطء في سهولة تحريك مفصل الركبة.

S6 كيف تكون شدّة التصلب في ركبتك بعد الاستيقاظ صباحاً؟

لا يوجد تصلب	خفيفة	متوسطة	شديدة	شديدة جداً
□	□	□	□	□

S7 كيف تكون شدّة التصلب في ركبتك بعد الجلوس أو الاستلقاء أو الراحة في نهاية اليوم؟

لا يوجد تصلب	خفيفة	متوسطة	شديدة	شديدة جداً
□	□	□	□	□

الألم

P1 كم مره تشعر بألم في الركبة؟

أبداً	شهرياً	اسبوعياً	يومياً	دائماً
□	□	□	□	□

ما هو مقدار **ألم** الركبة الذي عانيته **الأسبوع الماضي** أثناء أداء الأنشطة التالية:

P2 الإلتواء/اللف على ركبتك

لا يوجد ألم	خفيف	متوسط	شديد	شديد جداً
□	□	□	□	□

P3 مدّ الركبة بالكامل

لا يوجد ألم	خفيف	متوسط	شديد	شديد جداً
□	□	□	□	□

P4 ثني الركبة بالكامل

لا يوجد ألم	خفيف	متوسط	شديد	شديد جداً
□	□	□	□	□

P5 المشي على سطح مستوي

لا يوجد ألم	خفيف	متوسط	شديد	شديد جداً
□	□	□	□	□

P6 صعود أو نزول الدرج

لا يوجد ألم	خفيف	متوسط	شديد	شديد جداً
□	□	□	□	□

P7 في فراشك أثناء الليل

لا يوجد ألم	خفيف	متوسط	شديد	شديد جداً
□	□	□	□	□

P8 الجلوس أو الإستلقاء

لا يوجد ألم	خفيف	متوسط	شديد	شديد جداً
□	□	□	□	□

P9 الوقوف باستقامة

لا يوجد ألم	خفيف	متوسط	شديد	شديد جداً
□	□	□	□	□

الوظائف، أنشطة الحياة اليومية

الأسئلة التالية تتعلق بالوظائف البدنية، ونعني بذلك قدرتك على التنقل والاعتناء بنفسك.
لكل نشاط من الأنشطة التالية يرجى تحديد **درجة الصعوبة** التي واجهتها **الأسبوع الماضي** بسبب الركبة.

A1 نزول الدرج

لا يوجد صعوبة	خفيفة	متوسطة	شديدة	شديدة جداً
□	□	□	□	□

A2 صعود الدرج

لا يوجد صعوبة	خفيفة	متوسطة	شديدة	شديدة جداً
□	□	□	□	□

لكل نشاط من الأنشطة التالية يرجى تحديد **درجة الصعوبة** التي واجهتها **الأسبوع الماضي** بسبب الركبة.

A16 الأعمال المنزلية الثقيلة (نقل الصناديق الثقيلة، ونظافة أرضيات المنزل...الخ)

لا يوجد صعوبة	خفيفة	متوسطة	شديدة	شديدة جداً
☐	☐	☐	☐	☐

A17 الأعمال المنزلية الخفيفة (الطبخ وتنظيف الغبار...الخ)

لا يوجد صعوبة	خفيفة	متوسطة	شديدة	شديدة جداً
☐	☐	☐	☐	☐

الوظائف، الأنشطة الرياضية والترفيهية

الأسئلة التالية تتعلق بوظائفك البدنية عندما تمارس أنشطة عالية الجهد، يجب أن تكون الإجابة على هذه الأسئلة بناء على **درجة الصعوبة** التي واجهتها **الأسبوع الماضي** بسبب الركبة.

SP1 وضعية القرفصاء (الجلوس على المرحاض العربي)

لا يوجد صعوبة	خفيفة	متوسطة	شديدة	شديدة جداً
☐	☐	☐	☐	☐

SP2 الجري

لا يوجد صعوبة	خفيفة	متوسطة	شديدة	شديدة جداً
☐	☐	☐	☐	☐

SP3 القفز

لا يوجد صعوبة	خفيفة	متوسطة	شديدة	شديدة جداً
☐	☐	☐	☐	☐

SP4 الإلتواء أو اللف على ركبتك المصابة

لا يوجد صعوبة	خفيفة	متوسطة	شديدة	شديدة جداً
☐	☐	☐	☐	☐

SP5 الارتكاز على الركبتين (الجلوس بين السجدتين)

لا يوجد صعوبة	خفيفة	متوسطة	شديدة	شديدة جداً
☐	☐	☐	☐	☐

جودة الحياة

Q1 كم مره تدرك وتتذكر أن لديك مشكلة في الركبة؟

أبداً	شهرياً	اسبوعيًا	يومياً	باستمرار
☐	☐	☐	☐	☐

Q2 هل قمت بتعديل نمط حياتك لتجنب الضرر المحتمل من بعض الأنشطة على ركبتك؟

لا على الإطلاق	بشكل بسيط	بشكل متوسط	بشكل كبير	بشكل كُلي
☐	☐	☐	☐	☐

Q3 ما مدى تضايقك بسبب ضعف ثقتك في ركبتك؟

لا على الإطلاق	بشكل بسيط	بشكل متوسط	بشكل كبير	بشكل كُلي
☐	☐	☐	☐	☐

Q4 بشكل عام، ما مقدار الصعوبة التي تواجهها مع ركبتك؟

لا يوجد صعوبة	خفيف	متوسط	شديد	شديد جداً
☐	☐	☐	☐	☐

شكراً جزيلاً لإجابتك على كل الأسئلة في هذه الاستبانة.

16.4. Appendix D: International Physical Activity Questionnaire

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ **days per week**

   ☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   _____ **hours per day**

   _____ **minutes per day**

   ☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

   _____ **days per week**

   ☐ No moderate physical activities → ***Skip to question 5***

SHORT LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised August 2002.

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

SHORT LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised August 2002.

الصيغة المختصرة لاستبانة النشاط البدني الدولية، للاستخدام بواسطة التعبئة الشخصية

نحن مهتمون بمعرفة أنواع الأنشطة البدنية التي يقوم بها الأفراد كجزء من حياتهم اليومية. الأسئلة التالية ترتكز حول الوقت الذي قضيته في ممارسة أنشطة بدنية خلال الأيام السبعة الماضية. فضلاً أجب عن كل سؤال من الأسئلة التالية حتى وإن كنت تعتبر نفسك غير نشيط بدنياً. فكر في الأنشطة البدنية التي تمارسها خلال عملك، وكجزء من أعمالك المنزلية، وأثناء تنقلك من مكان لآخر، وتلك التي تقوم بها في وقت فراغك بغرض الترويح أو التمرين أو الرياضة.

الآن فكر في جميع الأنشطة البدنية التي تتطلب جهداً بدنياً مرتفع الشدة والتي قمت بممارستها خلال الأيام السبعة الماضية. الأنشطة البدنية مرتفعة الشدة هي تلك الأنشطة التي تجعل تنفسك أعلى بكثير من المعتاد، مثل رفع أشياء ثقيلة، أو حرث الأرض، أو ركوب الدراجة بسرعة عالية، أو الجري، أو ممارسة كرة القدم، أو كرة السلة، أو السباحة، أو نط الحبل. فكر فقط في الأنشطة البدنية مرتفعة الشدة التي قمت بممارستها لمدة ١٠ دقائق على الأقل في كل مرة.

١ – خلال الأيام السبعة الماضية، كم يوماً مارست فيه نشاطاً بدنياً مرتفع الشدة؟

____ يوم في الأسبوع

☐ لا أقوم بأي نشاط بدني مرتفع الشدة. ⟵ **انتقل مباشرة إلى السؤال رقم ٣**

٢ – في المعتاد، كم من الوقت قضيته في ممارسة نشاط بدني مرتفع الشدة في أحد تلك الأيام؟

____ ساعة في اليوم

____ دقيقة في اليوم

☐ لا أدري/ أو غير متأكد.

الآن فكر في جميع الأنشطة البدنية التي تتطلب جهداً بدنياً **معتدل الشدة** والتي قمت بممارستها خلال الأيام السبعة الماضية. الأنشطة البدنية معتدلة الشدة هي تلك الأنشطة التي تجعل تنفسك أعلى من المعتاد إلى حداً ما، ويمكن أن تتضمن رفع أشياء خفيفة، أو ركوب الدراجة بسرعة عادية، أو ممارسة كرة الطائرة، أو ممارسة تنس الطاولة، أو كنس المنزل، أو غسل الملابس يدوياً، أو غسل السيارة. لا تحسب المشي ضمن هذه الأنشطة. مرة أخرى، فكر فقط في الأنشطة البدنية معتدلة الشدة التي قمت بممارستها لمدة ١٠ دقائق على الأقل في كل مرة.

٣- خلال الأيام السبعة الماضية، كم يوماً مارست فيه نشاطاً بدنياً معتدل الشدة؟

____ يوم في الأسبوع

☐ لا أقوم بأي نشاط بدني معتدل الشدة. ← **انتقل مباشرة إلى السؤال رقم ٥**

٤- في المعتاد، كم من الوقت قضيته في ممارسة نشاط بدني معتدل الشدة في أحد تلك الأيام؟

____ ساعة في اليوم

____ دقيقة في اليوم

☐ لا أدري/ أو غير متأكد.

الآن فكر في الوقت الذي قضيته في المشي خلال الأيام السبع الماضية، ويتضمن ذلك المشي إلى العمل، والمشي أثناء العمل، وفي البيت، وخلال انتقالك من مكان لآخر، أو أي نوع من أنواع المشي بغرض الترويح أو الرياضة.

٥- خلال الأيام السبعة الماضية، كم يوماً مارست فيه **المشي** لمدة ١٠ دقائق على الأقل في كل مرة؟

____ يوم في الأسبوع

☐ لا أقوم بممارسة المشي إطلاقا. ← **انتقل مباشرة إلى السؤال رقم ٧**

٦- في المعتاد، كم من الوقت قضيته في ممارسة المشي في أحد تلك الأيام؟

____ ساعة في اليوم

____ دقيقة في اليوم

☐ لا أدري/ أو غير متأكد.

الآن فكر في الوقت الذي قضيته جالساً خلال الأيام السبعة الماضية. أحسب وقت الجلوس في العمل، وفي المنزل، وفي الدراسة، وفي الترفيه. من الممكن أن يتضمن ذلك وقت الجلوس على المكتب، وأثناء العمل على الكمبيوتر، وأثناء زيارتك لصديق، وأثناء القراءة، والجلوس أو الاستلقاء لمشاهدة التلفزيون.

٧- خلال الأيام السبعة الماضية، كم من الوقت قضيته جالساً في أحد هذه الأيام من غير أيام الإجازة الأسبوعية؟

____ ساعة في اليوم

____ دقيقة في اليوم

☐ لا أدري/ أو غير متأكد.

(نهاية الاستبانة، شكراً لمشاركتكم)

16.5. Appendix E: Sub-maximal Exercise Test Form

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Physical Fitness and physical activity levels, in individual with knee osteoarthritis and healthy controls

submaximal exercise test
(siconolfi protocol)

Patient identification: **70% of Age-predicted HR:**

Watts	Time	Heart rate	Borg
	Rest		
Start at 25 w			
50 w	2 min		
75 w	4 min		
100 w	6 min		
125 w	8 min		
150 w	10 min		
175 w	12 min		
200 w	14 min		
225 w	16 min		

Duration	Workload	70% of APHR	Age	Height	Weight

Predication equation:

Male: VO2 (L/min) = $0.348(X_1) - 0.035(X_2) + 3.011$
Female: VO2 (L/min) = 0.302(X1) – 0.019(X2) + 1.593
(X1= VO2 (L/min) from the original nomogram, X2 is the age in years)

predicted VO2max = L/min

L/min to ml/kg/min:

VO2max (L/min) ÷ weight = x1000

predicted VO2max = ml/kg/min

Calories burned per minute:

VOmax (L/MIN) x 5 = Kcal/min

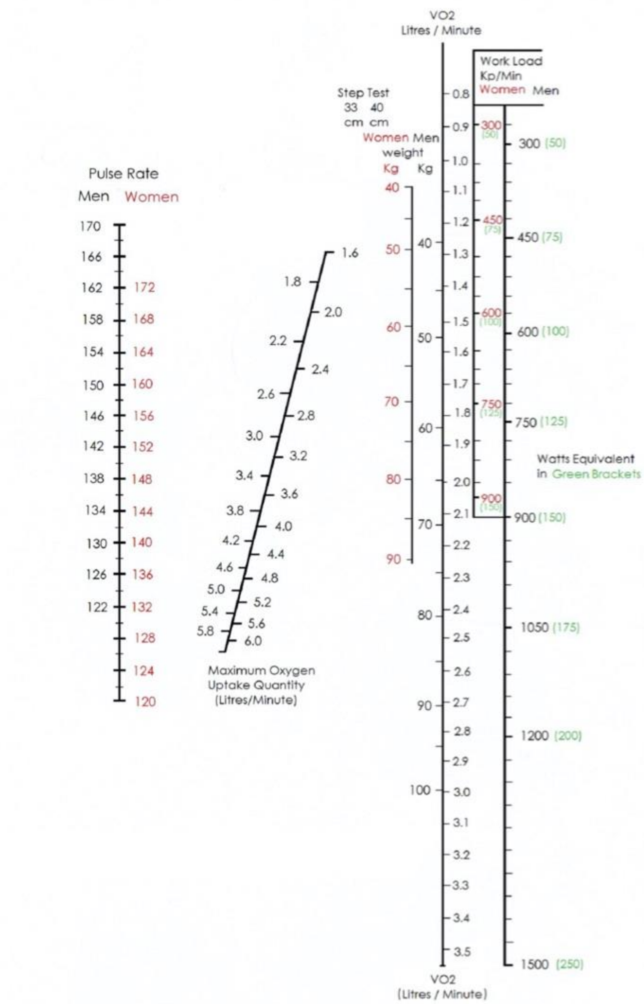
Total burned fat:

Calories burned per minute x Duration = calorie

METs:

VO2max (ml/kg/min) ÷ 3.5 = METs

Modified Astrand-Ryhming Nomogram



Reference: ACSM Guidelines for Exercise Testing & Prescription, Edition 5

16.6. Appendix F: Balance Test Form

Physical Fitness and physical activity levels, in individual with knee osteoarthritis and healthy controls

Timed Up and Go

Patient Identification:

trials	Time (sec)
1st	
2nd	
3rd	

Comments:
……
……
……

Investigator: **Date:**

16.7. Appendix G: Flexibility Test Form

Physical Fitness and physical activity levels, in individual with knee osteoarthritis and healthy controls

Chair Sit-and-Reach Test

Patient Identification Number:

Right Hamstrings	Left Hamstrings

Comments:
………
………
………

Investigator: Date:

16.8. Appendix H: Ethical Approval for Phase One

School of Healthcare Sciences
Head of School and Dean Professor Heather Waterman

Ysgol Gwyddorau Gofal Iechyd
Pennaeth yr Ysgol a Deon Yr Athrawes Heather Waterman

CARDIFF UNIVERSITY
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15 June 2017

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Physical Fitness and physical activity levels, in individuals with knee osteoarthritis and healthy controls

At its meeting of **13 June 2017**, the School's Research Ethics Committee considered your research proposal. The decision of the Committee is that your work should:

Pass –and that you proceed with your Research

The Committee has asked that the lead reviewers' comments be passed onto you and your supervisor, please see attached.

Please note that if there are any subsequent major amendments to the project made following this approval you will be required to submit a revised proposal form. You are advised to contact me if this situation arises. In addition, in line with the University requirements, the project will be monitored on an annual basis by the Committee and an annual monitoring form will be despatched to you in approximately 11 months' time. If the project is completed before this time you should contact me to obtain a form for completion.

Please do not hesitate to contact me if you have any questions.

Yours sincerely

Mrs Liz Harmer – Griebel
Research Administration Manager

Cc : Kate Button

16.9. Appendix I: Criteria for Termination of Exercise Testing

BOX 5.2 Indications for Terminating Exercise Testing

ABSOLUTE INDICATIONS

- Drop in systolic BP of ≥10 mm Hg with an increase in work rate, or if systolic BP decreases below the value obtained in the same position prior to testing when accompanied by other evidence of ischemia
- Moderately severe angina (defined as 3 on standard scale)
- Increasing nervous system symptoms (*e.g.*, ataxia, dizziness, or near syncope)
- Signs of poor perfusion (cyanosis or pallor)
- Technical difficulties monitoring the ECG or SBP
- Subject's desire to stop
- Sustained ventricular tachycardia
- ST elevation (+1.0 mm) in leads without diagnostic Q waves (other than V_1 or aVR)

RELATIVE INDICATIONS

- Drop in systolic BP of ≥10 mm Hg with an increase in work rate, or if systolic BP below the value obtained in the same position prior to testing
- ST or QRS changes such as excessive ST depression (>2 mm horizontal or downsloping ST-segment depression) or marked axis shift
- Arrhythmias other than sustained ventricular tachycardia, including multifocal PVCs, triplets of PVCs, supraventricular tachycardia, heart block, or bradyarrhythmias
- Fatigue, shortness of breath, wheezing, leg cramps, or claudication
- Development of bundle-branch block or intraventricular conduction delay that cannot be distinguished from ventricular tachycardia
- Increasing chest pain
- Hypertensive response (SBP of >250 mm Hg and/or a DBP of >115 mm Hg).

aVR, augmented voltage right; BP, blood pressure; DBP, diastolic blood pressure; ECG, electrocardiogram; PVC, premature ventricular contraction; SBP, systolic blood pressure; V_1, chest lead I.
Reprinted with permission from (25).

16.10. Appendix K: Interview Schedule

Physical Fitness, Physical Inactivity, and Physical Therapy Management of Knee OA in Saudi Arabia

Interview Topic Schedule

Topic 1. Experience

- Please could you start by telling me about what experience you have had in treating people with knee osteoarthritis?

Prompts (when graduated, types of jobs, responsibilities, CPD in OA, on the job v formal training, what are the typical numbers and characteristics of the OA population you treat

Topic 2. Operationalisation of care for knee OA

- Can you talk me through the typical patient journey or care pathway for individuals with knee osteoarthritis in your locality?

Prompts: who/ where do the referrals come from, are referrals required, what is the nature of the referrals, what professions are involved in the pathway, key factors used in decision making in care pathway,

- Can you describe any strengths or weaknesses in the current patient pathway or journey?

  Prompts: quality of referrals, timing of referrals, communication between professions, professional respect, patient role

- What are the main treatments offered to patients with knee osteoarthritis on this pathway?

Topic 3. Physical Therapy Experience

- Could you please tell me about your experience of the treatment you received for knee osteoarthritis?

Prompts: how long you have been receiving the treatment (number of sessions, duration), delivery method (group, individual, home exercise, self-management), equipment, exercise approaches, what type of interventions, success of interventions

Topic 4. Physical Activity

- How do you consider your physical activity level, what could limit or assist your physical activity participation?

Prompts: type of activity, duration, importance to your health)

- During your treatment journey, did anyone from the healthcare providers advised you to consider increasing physical activity?

Prompts: type of advice (leaflet, speech), follow up, perception on the advises)

- Based on your experience what is your recommended approach to improving physical fitness and physical activity?

Prompts: effective/ in effective treatment modalities, how much treatment (number of sessions and duration), delivery method (group, individual, home exercise, self-management), equipment, exercise approaches, policy, strategies

Topic 5. International guidelines and recommendations

- Are there any international guidelines or recommendations that you refer to?

Prompts: are barriers and facilitators to implementing these guidelines (culture, environment, population etc)...

Topic 6. Opinions about our current research findings around physical fitness, activity and weight management in OA

- Give participant infographic of current findings (individuals with OA in SA are less active and have higher BMI than matched controls but in addition % controls were sedentary and % were overweight or obese)

Prompts: reflection of population you treat and wider society, implications for physiotherapy treatment, influencing factors, barriers to treatment (environment, culture) strategies for future care pathway

Topic 7. Future and other comments or thoughts

16.11. Appendix L: Participants Information Form for Phase Two

Phase 2

Participant name: **Participant Identification:**

Age:

Sex: ◯ M ◯ F

Nationality: ◯ Saudi ◯ Non-Saudi

Level of education: ◯ BSc ◯ MSc ◯ PhD ◯ Other: ______

Work Setting: ◯ Public ◯ Private

Work Position:

Years of Experience/ living with arthritis:

Location of Work:

interest/ specialty:

Group:

Investigator: Date:

IELTS™

Test Report Form ACADEMIC

NOTE *Admission to undergraduate and post graduate courses should be based on the ACADEMIC Reading and Writing Modules.*
*GENERAL TRAINING Reading and Writing Modules are **not** designed to test the full range of language skills required for academic purposes.*
*It is recommended that the candidate's language ability as indicated in this Test Report Form be re-assessed **after two years** from the date of the test.*

Centre Number: SA100 | Date: 21/MAY/2016 | Candidate Number: [redacted]

Candidate Details

Family Name: SUBAHI

First Name: MOAYAD SALEH M

Candidate ID: L[redacted]

UKVI Number: I[redacted]

Date of Birth: 27/06/1988 | Sex (M/F): M | Scheme Code: Private Candidate

Country or Region of Origin:

Country of Nationality: SAUDI ARABIA

First Language: ARABIC

Test Results

Listening	**Reading**	**Writing**	**Speaking**	**Overall Band Score**	**CEFR Level**
7.0	7.0	6.0	7.0	7.0	C1

Administrator Comments

Centre stamp: BRITISH COUNCIL Jeddah

Validation stamp: IELTS

Administrator's Signature

Date: 31/05/2016 | Test Report Form Number: 1[redacted]A

BRITISH COUNCIL — idp IELTS AUSTRALIA — CAMBRIDGE ENGLISH Language Assessment, Part of the University of Cambridge

The validity of this IELTS Test Report Form can be verified online by recognising organisations at http://ielts.ucles.org.uk

16.13. Appendix N: Ethical Approval for Phase Two

School of Healthcare Sciences
Head of School and Dean Professor David Whittaker

Ysgol Gwyddorau Gofal Iechyd
Pennaeth yr Ysgol a Deon Yr Athrawes David Whittaker

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

20 June 2018

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Prifysgol Caerdydd
Ty Dewi Sant
Mynydd Bychan
Caerdydd CF14 4XN

Dear Moayad

Physical Fitness and physical activity levels, in individuals with knee osteoarthritis and healthy controls

I am writing to inform you that the Chair of the Research Ethics Committee has, following consultation, **approved** your revised research proposal. The Committee will ratify this decision at the next meeting on 10 July 2018 .

Please note that if there are any major amendments to the project you will be required to submit a revised proposal form. You are advised to contact me if this situation arises. In addition, in line with the University requirements, the project will be monitored on an annual basis by the Committee and an annual monitoring form will be despatched to you in approximately 11 months' time. If the project is completed before this time you should contact me to obtain a form for completion.

Please do not hesitate to contact me if you have any questions.

Yours sincerely

Mrs Liz Harmer Griebel
Research Administration Manager

c.c. Kate Button

16.14. Appendix O: Particiapnts information Form for Phase One

Physical Fitness and physical activity levels, in individuals with knee osteoarthritis and healthy controls

Participant name: **Participant Identification:**

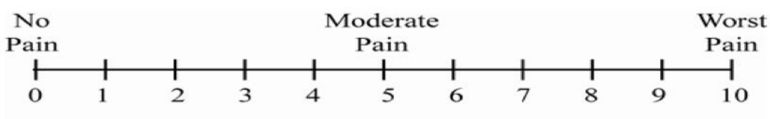
Age: ________ Sex: ________ Height: _________ DOB: __ /__ /__

Weight: _____ BMI: ________ Nationality: ________ COR: __________

Dominant side: ___

Clinical Presentation:

Knee Pain	
Age 45 or over	
Stiffness	
Crepitus	
Bony Tenderness	
Bony Enlargement	
No Palpable Warmth	



Investigator: Date:

16.15. Appendix P: Summary of Studies on Physicians Perceptions of Physiotherapy Service Within The Healthcare System in Saudi Arabia

Author	Study type	Population	Outcome measure	Results	Limitations
Eisa et al. (2016)	Cross-sectional	280 physicians with different specialties	awareness, perception and beliefs of physicians working in Saudi Arabia about physiotherapy with a 22-item online questionnaire	51% of respondents stated having some knowledge that mainly came from awareness lectures (17%) and specialised training (35%). only 11% reported that they refer individuals regularly, while the majority (49%) never referred individuals to physiotherapy perception of the physician towards physiotherapy was found to be negative (58%) 20% of physicians included prescriptions of treatment in their referrals 55% not comfortable about	the variety of specialties included in this study, may not necessarily have a connection with physiotherapy and their referral system might be through other specialties.

				referring individuals to PT departments without prescriptions	
Alshehri et al. (2018)	Cross-sectional	108 responded	Healthcare provider attitude, experience and the utilisation of physiotherapy service in Saudi Arabia with an online questionnaire	Only 50% believed physiotherapists could prescribe exercise programs 44% felt physiotherapists are not qualified for providing healthcare. 56% who did not agree with the statement that physiotherapists can assess individuals Only 17.6% agree with direct access to physiotherapists without a referral 85.2% believed that physiotherapy services have a vital role in secondary care 59.3% had experience working with physiotherapists physicians were confident to refer	small sample size with unidentified physician specialties and the inappropriate structure of questions may direct the respondents towards biased answers

				their individuals to physiotherapists	

16.16. Appendix Q: Quality Scores using AGREE II Instruments for included CPGs on knee OA.

Domain/Guideline	EULAR (2013)[*]	NICE (2014)[†]	ESCEO (2019)	OARSI (2019)	ACR & AF (2020)
Domain 1: Scope and Purpose	56%	100 %	66.6%	100%	83%
Domain 2: Stakeholder involvement	78%	100 %	100%	83.3%	66.6%
Domain 3: Rigour of Development	57%	91.66%	75%	83.3%	83%
Domain 4: Clarity of Presentation	89%	88.88%	100%	100%	88.8%
Domain 5: Applicability	0%	70.83%	83.3%	70%	8.3%
Domain 6: Editorial Independence	13%	95.83%	50%	100%	58%

[*] AGREE II scores were adapted from Brosseau et al. (2014) study

[†] AGREE II scores were adapted from Altman et al. (2015) study

16.17. Appendix R: Summary of Studies on Physiotherapists Evidence-based Practice in Knee OA

Author	Study type	Population	Outcome measure	Results	Limitations
Spitaels et al. (2019)	Cross-sectional	235 individuals with knee OA from Belgium	survey based on both process and outcome quality indicators	overall low adherence by physicians and physiotherapists to CPGs by 38% the lowest adherence to the recommendations of patient education about weight loss (24.3%) and managing loads at the knee joint (22.6%). 43% reported they were educated about the importance of exercise only 40.7% reported that they were referred to physiotherapy strengthening and functional exercises were administered by the majority of physiotherapists (83.6%) aerobic exercises and physical activity advice were not reported	reported questionnaires are based on the ability of the individuals to remember and recall the treatments
Spitaels et al. (2017)	Cross-sectional	284 physiotherapists from Belgium	guideline adherence by measuring a set of nine quality indicators	80% have offered patient education about the importance of exercise, and a tailored strengthening and functional exercises.	

				lack of patient education about weight loss and self-management the application of controversial/not recommended interventions such as massage (49%) and thermotherapy (24%),	
Jansen et al. (Jansen et al. 2010)	prospective cohort study	45 physiotherapists from the Netherlands	the adherence to CPGs using the process and outcome quality indicators	only 10% of participants adhered to the recommendations of education about physical activity and home exercise. Physical modalities such as TENS and US and massage therapy were used with 17% and 8% of individuals, respectively. Exercises were implemented among 87% of therapists.	
Ingelsrud et al. (2019)	Cross-sectional	517 knee OA individuals based in Denmark	questionnaire regards the previously received physiotherapy treatment	only 22% reported received exercises insoles and patient education about the disease and management options received even lower percentages (7% and 9%, respectively). Participants received massage (9%), stretching (9%), electrotherapy (5%) and acupuncture (7%).	
Jamtvedt et al. (2008)	Case-control	297 physiotherapists	Reported management of one patient for 12	98% had used exercise and 68% used patient education	

			sessions, compared to CPGs	35% of physiotherapists have used acupuncture, low-level laser therapy or TENS 42% did not provide advice for weight loss for obese individuals, Reported interventions such as: traction (46%), massage (54%), stretching (46%), tape (3%) and US (16%).	

16.18. Appendix S: Initial Categories from Analysis of All Data

Attitude towards physiotherapy
Education
Awareness
Evidence-based practice
Gender differences
Generational differences
Lifestyle
Multidisciplinary team
Ownership
Pathways of care
Individuals' characteristics
Physiotherapy service
Promotion of PA
Response to treatment
Perceptions of PA

16.19. Appendix T: Comparison of Categories Between Groups

Category/ group	Individuals	Physiotherapists	physicians	Healthy	others
attitude towards physiotherapy	x	x	x		
education	x	x	x	x	x
awareness	x	x	x	x	x
evidence-based practice		x	x		
gender differences	x	x	x	x	x
generational differences					x
lifestyle	x	x	x	x	x
multidisciplinary team		x	x		
Ownership	X	x	x	x	x
pathways of care	x	x	x		
individuals' characteristics		x	x		
physiotherapy service	x	x	x		
promotion of PA	x	x	x	x	x
response to treatment	x				
perceptions of PA	x	x	x	x	

16.20. Appendix U: Initial themes, categories and codes

Initial Theme 1: Diverse Management of Knee OA

Code	Category	Theme
• Treatment progression • Diagnosis of knee OA • Referral progression • Healthcare workload • Treatment options • Lack of monitoring • Physician lea decisions • Individual centred care • Suggested solutions to improve Healthcare services • Individuals first contact with Healthcare providers • Referral decisions • Variation of care	Pathways of care	Diverse Management of Knee OA

• Referral reports
• Interprofessional roles
• Multidisciplinary team
• Physiotherapists autonomy
• Referrals
    ○ Referral progression
    ○ Referral decisions
    ○ Referral to nutrition
• Medical statistics
• Professional communication
• Gatekeeper
• Professional responsibility
	Multidisciplinary team	

○ Shifting responsibility ○ Healthcare providers referrals to gyms ○ Delays in public clinics ○ Reasons for referral to physiotherapy		
• Response to physiotherapy Treatment • Response to medical treatment • Individuals experience with Healthcare providers • Response to gym treatment	Response to treatment	
• Clinical presentation • Patient's demography • Signs and symptoms • Rate of knee OA cases	Individuals' characteristics	

Initial Theme 2: Evidence-Based Practice in Physiotherapy

• Patient's awareness of physical Therapy • Physicians' attitude towards Physical therapy • Personal trainer understanding of physical therapy	Attitude towards physiotherapy	Evidence-Based Practice in Physiotherapy
• Physiotherapists adherence to Guidelines • Healthcare providers awareness and attitude towards guidelines • Physiotherapists Locus of Control	Evidence-based practice	

• Illegal medical practice in gyms • Lack of monitoring • Local guidelines • Barriers to guidelines • Suggested solutions to promote Adherence to guidelines		
• Physiotherapy clinics at primary healthcare centres • Reasons for discharge and withdrawal from physiotherapy • Speed of referral and access to Physiotherapy • Access to physiotherapy • Physiotherapists treatment Duration • Physiotherapy treatment plan • Physiotherapists decision Making for the treatment plan • Reasons for referral to Physiotherapy	Physiotherapy service	
• Patient's awareness of PA • Community awareness of PA • Patient's awareness of knee OA • Patient's awareness of physical Therapy	Awareness	Lack of Education and Awareness
• Patient education about pa • Patient education about treatment options • Patient education about the disease	Education	

• Patient education about weight loss • Teacher efforts to educate students about pa • Sports education at schools • Suggested solutions to promote pa in schools		

Initial Theme 3: The Culture of Physical Inactivity

• Healthcare providers opinion on individuals PA • Personal trainer opinion on community PA • Teacher opinion on students PA • PA in Saudi Arabia • Teacher opinion on community PA	Perceptions of PA	The Culture of Physical Inactivity
• The senior adults' stereotype image • Teens and young adults' awareness of pa • Senior adults' participation in gyms	Generational differences	
• The female cultural barrier to PA • Barriers for female PA • Female only gyms	Gender differences	
• Lack of sufficient efforts to promote PA • Suggested solutions to promote PA • Facilitators to PA • Government efforts to promote PA in schools • Inability to deliver the message to promote PA	Promotion of PA	

• The attitude towards changing PA of the community in Saudi Arabia • Rewards for PA • Healthcare providers assessment of pa of individuals • Responsibility of promoting PA • Government effort to promote PA • Healthcare providers efforts to promote PA in the community • Motivators for students to be physically active		
• Community experience with PA gyms • PA level • Community barriers to PA • Priority of PA • Habit of PA • Purpose of gym visits • Individuals' barriers to PA • Reasons to do PA • Desire to change	Lifestyle	
• Community and patient's locus of control • Patient's adherence to the advice • Individuals take shorter and easier treatment options • Patient's self-referral to gyms • Ownership	Ownership	Control Over Life

16.21. Appendix V: Patient information sheet

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

معلومات وارشادات بحث

(اللياقة البدنية ومستويات النشاط البدني، في الأفراد الذين يعانون من مرض خشونة العظام في مفصل الركبة)

أنت مدعو للمشاركة في دراسة بحثية لأنك إما فرد يعاني من آلام في الركبة تتعلق بمرض خشونة العظام أو أنك لا تواجه أي آلام في الركبة. تجري هذه الدراسة في جامعة كارديف ببريطانيا وجامعة أم القرى في السعودية. قبل أن تقرر إذا كنت ترغب في المشاركة، من المهم بالنسبة لك أن تفهم لماذا يتم إجراء هذا البحث وما سوف ينطوي على المشاركة فيه. يرجى تخصيص بعض الوقت لقراءة هذه المعلومات بعناية. سيقوم أحد الباحثين بمراجعة ورقة المعلومات معك. الرجاء الاستفسار إذا كان هناك شيء غير واضح أو إذا كنت ترغب في المزيد من المعلومات. ناقش الآخرين إذا رغبت في ذلك قبل أن تقرر ما إذا كنت ترغب في المشاركة أم لا.

ما هو الغرض من هذه الدراسة؟

الهدف من هذا البحث هو معرفة مستويات اللياقة البدنية والنشاط في الأفراد الذين يعانون من آلام في الركبة نتيجة لالتهاب وخشونة المفصل. على وجه الخصوص، نحن مهتمون لمعرفة مقدار الطاقة الحركية المستهلكة يوميا من قبل مرضى خشونة الركبة وهل هم يعانون من الإرهاق اثناء الحركة. نود أيضا أن نتعرف على الأعراض الاخرى التي يواجهونها، وما هي العوامل الهامة في تشجيعهم أو منعهم من ممارسة الرياضة. وسوف نقارن هذه المعلومات بالبيانات التي تم جمعها من الافراد الذين لا يعانون من التهاب وخشونة مفصل الركبة.

هل يجب علي المشاركة؟

هو فقط قرارك أنت إذا كنت تريد المشاركة أو لا. إذا قررت المشاركة، ستحصل على ورقة المعلومات هذه لقراءتها بتمعن وبعد ذلك يطلب منك التوقيع على نموذج الموافقة على المشاركة في البحث. إذا قررت المشاركة، فإنك لا تزال حر في الانسحاب في أي وقت دون إبداء سبب. إن قرار عدم المشاركة أو الانسحاب في أي وقت لن يؤثر على مستوى الرعاية التي تتلقاها. إذا قررت عدم المشاركة، فليس عليك تقديم سبب لهذا القرار، فقط ابلاغنا بذلك.

لماذا طلب منك المشاركة؟

نحن نبحث عن الأفراد الذين هم:

- 45 سنة فما فوق.
- قد تم او **لم يتم** تشخيصهم بمرض التهاب وخشونة مفصل الركبة.
- قد **تعاني** أو **لا تعاني** من آلام في الركبة.
- لا توجد لديك حالة طبية لا تسمح لك بممارسة الرياضة. (مثل نقص التروية، جلطة قلبية وذبحة صدرية غير مستقرة، ومرض عدم انتظام ضربات القلب غير المنضبط، تضيق عرق الأبهر غير المنضبط، أعراض فشل القلب، امراض رئوية حادة، التهاب عضلة القلب الحاد، تمدد الأوعية الدموية او امراض معدية).

ماذا على أن أفعل؟

ستشمل المشاركة على حضور جلسة اختبار واحدة في جامعة ام القرى، كلية العلوم الطبية التطبيقية، قسم العلاج الطبيعي. قد تستغرق الجلسة حوالي ساعة و ٣٠ دقيقة. قبل البدء سوف يطلب منك التوقيع على استمارة الموافقة بعد مراجعة ورقة المعلومات مع الباحث. لقياس مستويات الطاقة الحركية الخاصة بك، سوف نطلب منك الجلوس على دراجة وارتداء قناع على الفم والانف، وسوف نطلب منك اجراء تمرين على الدراجة لمدة ٦دقائق بجهد معتدل. أثناء الاختبار:

- ستتعرف وتتأقلم على معدات الاختبار والدراجة، وسوف نقوم بتسجيل معدل ضربات القلب خلال الراحة.
- ستؤدي فترة احماء قصيرة على الدراجة.
- سوف يطلب منك الحفاظ على سرعة مستقرة لمدة الاختبار، وسيتم التحكم في المقاومة. وسيتم قياس معدل ضربات القلب الخاص بك.
- سيتم تتبع معدل ضربات القلب الخاص بك طوال الاختبار.
- سيتم فحص مظهرك والأعراض والجهد بانتظام، لمراقبة أي اعراض لا سمح الله.
- سيتم إنهاء الاختبار بعد 6 دقائق أو عندما يصل معدل ضربات القلب إلى مستواه المحدد مسبقا (٧٠٪ من الحد الأقصى لمعدل ضربات القلب)، أو إذا طلبت التوقف، أو إذا واجهت حالة طارئة أو علامات غير طبيعية أو إذا فشلت في أداء الاختبار بدقة.
- ستعطى الوقت اللازم للراحة في نهاية الاختبار، حتى يعود معدل ضربات القلب إلى معدله الطبيعي قبل الاختبار.

سوف نطلب منك أيضا ملء بعض الاستبيانات حول أعراض الركبة التي تعاني منها، والعوامل التي تؤثر على قرارك بممارسة الرياضة. من المهم بالنسبة لك أن تدرك أنك تستطيع ان تتوقف عندما ترغب في ذلك بسبب التعب أو أي إزعاج آخر. هذا الاختبار لن يؤثر بأي حال من الأحوال على العلاج الذي تتلقاه.

ما هي الفوائد العائدة لك من المشاركة؟

لن تكون هناك فائدة مباشرة لك من خلال المشاركة في هذه الدراسة. لكن سوف تستخدم نتائج هذه الدراسة لوضع خطة علاجية جديدة وأكثر فعالية من شأنها أن تحسن اللياقة البدنية للمرضى وتمنعهم من الوصول إلى التعب بسهولة، وتشجيعهم على أن يكونوا بصحة بدنية أفضل، والتي قد تفيد المرضى في المستقبل.

هل هناك أي مخاطر في المشاركة في هذه التجربة؟

لن تكون هناك مخاطر صحية في المشاركة في الدراسة. القياسات اللياقية ستتطلب مستوى معتدل من الجهد من خلال الدراجة الثابتة، وبذلك تعتبر آمنة وغير ضارة. بالإضافة إلى ذلك، سيتم اجراء فحوصات لدراسة استعدادك قبل المشاركة. خلال التجربة، سيتم متابعة مستوى الجهد وكذلك العلامات الحيوية الخاصة بك. في أي وقت أثناء التجربة، يسمح لك بالانسحاب إذا كنت تشعر بعدم الأمان أو بالشعور انه لا يمكنك الاستمرار في الاختبارات.

ما الذي يمكن توقعه أثناء عملية توقيع الموافقة على المشاركة؟

سيتحقق أحد أعضاء فريق البحث إذا كنت مؤهلا للمشاركة في الدراسة وستناقشون معك عن ورقة معلومات البحث التي حصلت عليها مسبقا، سيتاح لك الوقت لطرح أي أسئلة. سيتم منحك يومين للنظر في المشاركة في الدراسة وطرح أي سؤال. إذا وافقت على المشاركة، فسيطلب منك التوقيع على نموذج الموافقة.

من يقوم بتنظيم وتمويل البحث؟

يجري تنظيم هذه الدراسة وتنفيذها كجزء من أطروحة دكتوراه من قبل طالب دكتوراه في العلاج الطبيعي واشراف جامعة كارديف ببريطانيا. ولا توجد مصادر تجارية للتمويل.

ماذا سيحدث إذا لم أرغب في الاستمرار في الدراسة؟

إذا انسحبت من الدراسة، فإننا سوف نمحو جميع المواد التي يمكن التعرف بها عليك.

ماذا لو توفرت معلومات جديدة؟

أحيانا أثناء تنفيذ مشروع بحثي، تتاح معلومات جديدة. إذا حدث ذلك، سوف يخبرك الباحث الرئيسي عن ذلك ويناقش معك ما إذا كنت ترغب في الاستمرار في الدراسة. إذا قررت المتابعة، سيطلب منك التوقيع على نموذج موافقة محدثة.

كيف سيتم الحفاظ على سرية معلوماتي؟

سيتم الاحتفاظ بجميع المعلومات التي تم جمعها عنك أثناء البحث بسرية تامة. سنقوم باستخدام البنية التحتية للحوسبة والتخزين الآمن داخل جامعة كارديف، والتي تلبي المعايير المحلية والوطنية للأمن والخصوصية. سيكون هذا محمي بكلمة مرور. سيتم تخزين استمارات الموافقة في خزانة إيداع قابلة للإقفال في غرفة مغلقة في جامعة كارديف. سيتم تخزين تفاصيل الاتصال بالمشارك في قاعدة بيانات في جامعة كارديف على الخادم الذي سيكون محمي بكلمة مرور. لن تتم مشاركة أي معلومات تقدمها مع أي شخص آخر. سيتم تخزين البيانات الخاصة بك لمدة ١٥ عاما ثم سيتم تدميرها تماشيا مع إجراءات حماية البيانات.

ماذا سيحدث للنتائج؟

وسيتم عرض نتائج الدراسة في الاجتماعات العلمية ونشرها في المجلات المتخصصة في الرعاية الصحية. لن يتم تحديدك شخصيا في أي تقرير ولكن قد نستخدم بعض التعليقات التي تقدمها لنا في تقاريرنا.

من قام بمراجعة هذه الدراسة؟

استعرضت هذه الدراسة من قبل لجنة أخلاقيات بحوث كلية العلوم الصحية في ويلز ولجنة البحوث الأخلاق هيئة البحوث الصحية (ريك) لويلز وكارديف ومجلس الصحة ومكتب البحوث والتطوير بجامعة فيل. تمت أيضا مراجعة هذه الدراسة من قبل جامعة أم القرى، الدراسات العليا بكلية العلوم الطبية التطبيقية وقسم العلاج الطبيعي.

ماذا لو أردت تقديم شكوى؟

إذا كنت قد تعرضت لأذى من خلال المشاركة في هذا البحث، لا توجد ترتيبات للتعويض. ولكن إذا تعرضت لأذى بسبب إهمال شخص ما، تستطيع التقدم بإتخاذ إجراء قانوني قد تضطر لدفع ثمنه. بغض النظر عن ذلك، إذا كنت ترغب في تقديم شكوى، أو لديك أي مخاوف بشأن أي جانب من جوانب الطريقة التي تم التعامل بها معك خلال هذه الدراسة، يرجى الاتصال بالباحث الرئيسي:

دكتور/ مؤيد سبحي

البريد الإلكتروني: [redacted]

جوال: [redacted]

إذا كنت ترغب في التحدث مع شخص مستقل عن الدراسة يرجى الاتصال بـ [redacted]

PARTICIPANT INFORMATION SHEET

Physical Fitness and physical activity levels, in individuals with knee osteoarthritis and healthy controls

You are being invited to take part in a research study because you are either an individual who suffers with knee pain related to osteoarthritis or you are an individual that doesn't experience any knee pain. This study is taking place at Umm Al-Qura University. Before you decide if you want to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read this information carefully. One of our team will go through the information sheet with you. Ask us if there is anything that is not clear or if you would like more information. Discuss it with others if you wish, before you decide whether or not you wish to participate.

What is the Purpose of this study?

The aim of this project is to find out about the fitness and activity levels in individuals who have pain in their knee as a result of osteoarthritis. We also want to find out about the symptoms individuals experience in their knee and what factors are important in encouraging or stopping them from exercising. We will compare this information to data collected in individual that don't suffer with knee osteoarthritis.

Do I Have to Take Part?

It is solely your decision to decide if you want take part or not. If you do decide to participate, you will be given this information sheet to keep and after you have had enough time to read through it, be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time without giving a reason. A decision not to take part or to withdraw at any time will not affect the standard of care you receive. Should you decide not to take part, you do not have to provide a reason for such decision.

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Why have you been asked to take part?

We are looking for individuals who are:

- 45 years and older.
- may or may not be diagnosed with Knee Osteoarthritis.
- You may or may not have experienced knee pain.
- Does not have a medical condition that does not allow them to exercise. Such as ischemia, recent myocardial infarction (within 2 days), Unstable angina, Uncontrolled cardiac dysrhythmias, aortic stenosis, Uncontrolled symptomatic heart failure, Acute pulmonary embolus or pulmonary infarction, Acute myocarditis or pericarditis, aneurysm, systemic infection.

What will I have to do?

Taking part will involve attending a single testing session at Umm Al-Qura University, Physiotherapy department. The session might last approximately 1 hour and 30 minutes. Before starting you will be asked to sign a consent form after going through the information sheet with the investigator. You will undergo 4 tests to measure your physical fitness levels. An example of the tests is to measure your aerobic capacity, which we will ask you to sit on a bike to perform approximately 6 minutes' of moderate effort exercise. During the test:

- You will be familiarised with the bike, and we will record your resting heart rate.
- You will perform a short warm-up on the bike.
- You will be asked to pedal at a steady state for the duration of the test, resistance will be controlled and your heart rate will be measured.
- We will keep track of your heart rate throughout the test.
- Your appearance, symptoms and effort will be checked regularly.
- The test will be terminated after 6 minutes or when your heart rate reaches our pre-determined level (70% maximum heart rate), or if you request to stop, if you experience an emergency situation, abnormal signs or if you fail to perform the exercise test protocol accurately.
- We will give you time to cool down/ rest at the end of the test, until your heart rate returns to its normal rate before the test.

We will also ask you to fill in some questionnaires about your knee symptoms, and factors that influence your decision to exercise. It is important for you to realise that you may stop when you wish because of feelings of fatigue or any other discomfort. This test will in no way affect the treatment you receive.

What are the possible benefits of taking part?

There will be no direct benefit to you by taking part in this study. The findings of this study will be used to develop a new and potentially more effective treatment plan that might improve the patient's physical fitness and prevent them from reaching fatigue easily, and to encourage them to be physical active, which may benefit patients in the future.

Are there any risks in participating in this trial?

There will be no health risks in taking part of the study. The exercise testing in this study is going to at a moderate level of effort, through stationary bike, which is safe and harmless. In addition, you will be screened for your readiness to the tests prior to taking part in the study. During the test, your exertion level will be monitored as well as your vitals. Anytime during the study, you are allowed to withdraw if you feel unsafe or not feeling you can continue the tests.

What to expect during the consent process?

A member of your research team will have checked if you are eligible to be involved in the study. You will have been provided with the information sheet about the study. They will explain the study and go through the information sheet, and allow you time to ask any questions. You'll be given 2 days to consider participating in the study and to ask any question. If you agree to take part, then you will be asked to sign a consent form.

Who is organising and funding the research?

This study is being organized and carried out as a part of PhD thesis by Physical Therapy PhD student and supervisors in Cardiff University. There are no commercial sources of funding.

What will happen if I do not want to carry on in the study?

If you withdraw from the study, we will erase all identifiable material.

What if new information becomes available?

Sometimes during the course of a research project, new information becomes available about the investigation. If this happens, the lead researcher will tell you about it and discuss with you whether you want to continue in the study. If you decide to continue, you will be asked to sign an updated consent form

How will my information be kept confidential?

All information that is collected about you during the course of the research will be kept strictly confidential. We will be using the computing infrastructure and secure storage within Cardiff University, which meets local and national standards for security and privacy. This will be password protected. Consent forms will be stored in a lockable filing cabinet in a locked room in Cardiff University. Participant contact details will be stored in a database in Cardiff University on a server that will be password protected. Any information you provide will not be shared with anyone else. Your data will be stored for 15 years and then will be destroyed in line with data protection procedures.

What will happen to the results?

The results of the study will be presented at scientific meetings and published in journals for healthcare professionals. You will not be identified in any report/publication but we may use some of the comments that you provide us with in our reports.

Who has reviewed this study?

This study has been reviewed by the School of Healthcare Sciences Research Ethics Committee for Wales and the Health Research Authority Research Ethics Committee (REC) for Wales and Cardiff and Vale University Health Board, NHS Research and Development office.

What if I wish to lodge a complaint?

If you are harmed by taking part in this research, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action but you may have to pay for it. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact the Principal Investigator Moayad Subahi, email: [redacted] or mobile [redacted]. If you would like to talk to someone independent to the study please contact DR. Ashraf Abdulaal, School of Healthcare Sciences phone: [redacted]

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16.22. Appendix W: Consent form

نموذج موافقة على المشاركة في بحث

(اللياقة البدنية ومستويات النشاط البدني، في الأفراد الذين يعانون من مرض خشونة العظام في مفصل الركبة)

رقم المعرف: ____________

اسم الباحث: ____________

فضلا املأ المربع بالحرف الاول من الاسم الشخصي واسم العائلة

- أؤكد أنني قرأت ورقة المعلومات المؤرخة .... للدراسة أعلاه. لقد أتيحت لي الفرصة للنظر في المعلومات وطرح الأسئلة وتمت الاجابة بشكل مرض. ☐
- أفهم أن مشاركتي طوعية وأنني حر في الانسحاب في أي وقت دون إبداء أي سبب، بدون تأثر الرعاية الطبية أو الحقوق القانونية. ☐
- (إذا كان ذلك مناسبا) أفهم أن الأقسام ذات الصلة بالملاحظات الطبية الخاصة بي، والبيانات التي تم جمعها خلال الدراسة يمكن أن ينظر إليها من قبل أفراد من جامعة كارديف ومن السلطات التنظيمية، إذا كانت ذات صلة في المشاركة في هذا البحث. أعطي الإذن لهؤلاء الأفراد للوصول إلى سجلاتي لأغراض التدقيق. ☐
- (إذا كان ذلك مناسبا) أفهم أن المعلومات التي تم جمعها عني سوف تستخدم لدعم البحوث الأخرى في المستقبل، ويمكن أن تكون تشارك بشكل يحفظ خصوصية المشارك مع الباحثين الآخرين. ☐
- أوافق على المشاركة في الدراسة أعلاه. ☐

اسم المشارك/او من ينوبه: ____________ التوقيع: ____________ التاريخ: ____/____/____

Participant Identification Number for this study:

CONSENT FORM

Physical Fitness and physical activity levels, in individuals with knee osteoarthritis and healthy controls

Name of Researcher: Moayad Subahi

Please initial box

1. I confirm that I have read the information sheet dated 16/5/2017 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐
3. (If appropriate) I understand that relevant sections of my medical notes and data collected during the study may be looked at by individuals from Cardiff University, from regulatory authorities or from the NHS Trust, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records for audit purposes. ☐
4. (If appropriate) I understand that the information collected about me will be used to support other research in the future, and may be shared anonymously with other researchers. ☐
5. I agree to take part in the above study. ☐

______________________	______________________	______________________
Name of Participant	Date	Signature
______________________	______________________	______________________
Name of Person taking consent	Date	Signature

Version 1 16/5/2017

16.23. Appendix X: Arabic version of Barriers and Facilitators for PA survey

الأسئلة	الأجوبة		
كيف تؤثر شخصيتك على قرارك بممارسة الرياضة؟	سلبي ○	محايد ○	ايجابي ○
هل تؤثر صورتك الذاتية على قرارك بممارسة الرياضة؟	لا تؤثر ○	محايد ○	تؤثر ○
كيف تؤثر حالتك الصحية على قرارك بممارسة الرياضة؟	سلبي ○	محايد ○	ايجابي ○
كيف تؤثر معرفتك بأهمية النشاط البدني والتمارين الرياضية على قرارك بممارسة الرياضة؟	سلبي ○	محايد ○	ايجابي ○
هل الاستمتاع بعد التمرين يحفزك على مواصلة التمرين؟	لا تؤثر ○	محايد ○	تؤثر ○
هل تحفزك نتائج التمرين على مواصلة التمرين؟	لا تؤثر ○	محايد ○	تؤثر ○
كيف تؤثر تجربتك مع ممارسة الرياضة على قرارك بممارسة الرياضة؟	سلبي ○	محايد ○	ايجابي ○
كيف تقيم معرفتك بمرض خشونة العظام في الركبة؟	غير كافيه ○	محايد ○	كافيه ○
هل يؤثر ألم الركبة على قرارك بممارسة الرياضة؟	لا تؤثر ○	محايد ○	تؤثر ○
هل يؤثر نوع التمرين على قرارك بممارسة الرياضة؟	لا تؤثر ○	محايد ○	تؤثر ○
هل تؤثر نوعية النوم على قرارك بممارسة الرياضة؟	لا تؤثر ○	محايد ○	تؤثر ○
هل يؤثر تصلب الركبة على قرارك بممارسة الرياضة؟	لا تؤثر ○	محايد ○	تؤثر ○
هل يؤثر دعم الأسرة على قرارك بممارسة الرياضة؟	لا تؤثر ○	محايد ○	تؤثر ○
هل يؤثر دعم / تحفيز العلاج الطبيعي على قرارك بممارسة الرياضة؟	لا تؤثر ○	محايد ○	تؤثر ○
هل يؤثر دعم / تحفيز الطبيب على قرارك بممارسة الرياضة؟	لا تؤثر ○	محايد ○	تؤثر ○
كيف تؤثر النظافة الشخصية على قرارك بممارسة الرياضة	سلبي ○	محايد ○	ايجابي ○
كيف تؤثر حالة الطقس على قرارك بممارسة الرياضة؟	سلبي ○	محايد ○	ايجابي ○
هل يؤثر توفر شريك التدريب على قرارك بممارسة الرياضة؟	لا تؤثر ○	محايد ○	تؤثر ○
كيف تؤثر تكاليف الوصول إلى الصالات الرياضية أو مرافق التدريب على قرارك بممارسة الرياضة؟	سلبي ○	محايد ○	ايجابي ○
كيف تقيم توافر فصول التمرين في منطقتك؟	غير كافيه ○	محايد ○	كافيه ○
كيف يؤثر النقل على قرارك بممارسة الرياضة؟	سلبي ○	محايد ○	ايجابي ○
ما مدى أهمية التمرين والنشاط البدني بالنسبة لك؟	غير مهم ○	محايد ○	مهم ○
ما مدى أهمية ممارسة الرياضة والنشاط البدني لحالتك الصحية؟	غير مهم ○	محايد ○	مهم ○