Exploring the influence of maternal health behaviours in pregnancy on maternal and infant health and development

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List of Abbreviations

ABW	Average birthweight
AGA	Average for gestational age
ALSPAC	Avon Longitudinal Study of Parents and Children
BMI	Body mass index
BSID	The Bayley Scales of Infant Development
CBCL	Child Behaviour Checklist
CBQ	Child Behaviour Questionnaire
CBWC	Custom birthweight centiles
CI	Confidence interval
CICS	Cardiff Infant Contentiousness Scale
CPRS	Child-Parent Relationship Scale
DOHAD	Developmental Origins of Health and Disease
ELSPAC	European Longitudinal Study of Pregnancy and Child
EPDS	Edinburgh Postnatal Depression Scale
FFQ	Food frequency questionnaire
GDM	Gestational diabetes mellitus
GIW	Grown in Wales
GWG	Gestational weight gain
HBW	High birthweight
IBQ	Infant Behaviour Questionnaire
IQR	Interquartile range
LBW	Low birthweight
LGA	Large for gestational age
MOD	Mode of delivery
NHANES	National Health and Nutrition Examination Survey
NHS	National Health Service
NICE	The National Institute for Health and Care Excellence
PBQ	Postnatal Bonding Questionnaire
PCA	Principal component analysis
PRAMS	Pregnancy Risk Assessment Monitoring System
RCT	Randomised Control Trial
SGA	Small for gestational age
STAI	State-Trait Anxiety Inventory
UK	United Kingdom
WIMD	Welsh Index of Multiple Deprivation

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Declaration

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Summary

Introduction The pregnancy environment can influence the short and longer term health and development of both mother and infant. One such environmental influence is maternal health behaviours. However, the current evidence regarding the influence of prenatal health behaviours on a range of outcomes is often highly inconsistent, does not consider the effect of multiple health behaviours simultaneously and is rarely conducted in Wales.

Research questions 1) What are the health behaviours undertaken in pregnancy by women in Wales? 2) What is the influence of the maternal health behaviours in pregnancy on maternal and infant outcomes in Wales?

Method This thesis utilised data from the Grown in Wales cohort, based in South Wales. 355 women were recruited at the pre-surgical appointment for an elective caesarean section. This thesis utilised data from midwife recorded notes, questionnaires and infant assessments, collected at recruitment, one or four years postpartum.

Results During pregnancy, 11% of women smoked, 38.20% consumed alcohol, 16.60% undertook exercise and two dietary patterns were identified: Western and Health Conscious. A Health Conscious dietary pattern and exercise were associated with improved breastfeeding and mother-infant bonding outcomes, respectively. Alcohol, a Western dietary pattern and smoking were associated with suboptimal gestational weight gain, mental health and mother-child relationship outcomes. A Health Conscious dietary pattern was associated with improved birthweight and temperament outcomes, whilst smoking and alcohol were associated with suboptimal birthweight and language outcomes.

Conclusion Prenatal health behaviours play an important role in influencing maternal and infant health and development. Unlike other environmental influences in pregnancy, health behaviours are potentially modifiable. This research provides novel insight on the nature and influence of prenatal health behaviours in a South Wales population, and highlights potential behavioural targets for possible future interventions to improve outcomes for mothers and infants.

Chapter 1 - Introduction

1.1. Introduction

1.1.1. Pregnancy

Pregnancy is a unique period in which two (or more) individuals, the mother and the infant, are in intimate contact and the mothers behaviours will directly influence her offsprings outcomes. According to the most recently available data, there were 681,560 live births in 2020 in the United Kingdom (UK) alone (Office for National Statistics, 2021). Pregnancy is a period that involves extensive social, physiological, hormonal and psychological changes and demands that affect every organ system in the mother's body (Lockitch and Gamer, 1997, Otchet et al., 1999). This includes increased heart rate, oxygen demand, blood volume and even the development of a new transient organ, the placenta, so vital that without which successful pregnancies could not occur (DiPietro et al., 2019). These changes occur to help provide the optimal in-utero environment for the developing infant, as well as to prepare the mother not only for labour and delivery, but also to care for the infant when born (Lockitch and Gamer, 1997). The in-utero environment of the fetus during pregnancy is vital during this crucial period and adversities can have long lasting implications for the health of both mother and child. In the 1980s it was observed that poor nutrition during pregnancy, and later infant birthweight, was associated with increased risk of heart disease in later life (Barker and Osmond, 1986, Barker et al., 1989). These, and other observations, led to the development of the highly influential Developmental Origins of Health and Disease (DOHAD) theory, which hypothesises that suboptimal in-utero environment during pregnancy can affect development and thus influence the risk of long term health complications (Barker, 2004, Barker, 1990). Thus, optimising the pregnancy environment could have long lasting benefits.

Despite the high number of pregnancies every year and the associated future implications of poor maternal health, pregnancy is a highly neglected area of research. Indeed, there is mounting evidence that pregnancy related research is urgently required to improve outcomes for women and their children. A review by Fisk and Atun (2009) concluded that UK maternal and pregnancy health research is underfunded in comparison to other health areas, with less funding prioritised for this research compared to other countries. In 2015 the Chief Medical Officers in the UK produced a strong report focusing on the health of women (Mullins and Davies, 2015). This critical and compelling report emphasised that increased pregnancy related research was urgently required and that pregnancy complications should be highlighted as high priority for UK government research funding.

The report also recommended an urgent requirement for a review of current research expenditure on pregnancy needs in the UK. The resulting recently published review, commissioned by the UK Research Collaboration, provided further extensive evidence of the underfunding of pregnancy related research in the UK (Guthrie et al., 2020). The report identified that whilst pregnancy related care is estimated to cost the National Health Service (NHS) around £5.8 billion per year, only an average total of £51 million per year is spent on all pregnancy related research from all current funding providers. For every £1 spent on pregnancy-related care in the NHS, only around 1p is provided by funders for research. This is in direct comparison to other less prevalent health conditions such as stroke, dementia and heart disease, which receive 3p, 6p and 7p respectively. Indeed, between 2013 and 2017, only £255 million was provided for pregnancy research in the UK, reflecting only 2.40% of all direct health research funds by current funding institutes. Thus, it can clearly be seen that pregnancy is an underfunded and under-researched topic in the UK.

1.1.2. Wales

The birth rate in the UK as a whole has previously been highlighted, however, it is also important to consider the individual UK nations. The most recently available data has indicated that in Wales alone there were 28,884 live births in 2020 (Welsh Government, 2021). Whilst the lack of pregnancy related research in the UK in general is a severe issue, this becomes even more apparent when considering Wales, where there is a crucial paucity in this area. This lack of research in Wales, which will be highlighted throughout this thesis in relation to various outcomes, is a crucial oversight due to the devolved nature of the nation. In 1998 Wales became one of the devolved nations in the UK, allowing the Welsh Government to make separate decisions on legislature and executives to the overall UK government and governments of other UK nations (Torrance, 2019). Devolved powers gave Wales the responsibility for a variety of policy areas including Health and Social Care (Civil Service, 2019). This has resulted in differences between UK nations on important areas such as health systems, health priorities and consequently health outcomes (Bevan et al., 2014, NAS, 2012, Holland, 2010). Indeed, Wales no longer manages services via an internal market and Local Health Boards have been established. This has led to benefits that include medication, as in Wales prescription medication is free for all unlike other areas of the UK where only certain groups receive free prescriptions. Additionally, there are differences in maternity services strategies, with Wales developing and introducing its own policies such as ‘Maternity Care in Wales: a five year vision for the future (2019-2024) (Welsh Government, 2019b) and the Wellbeing of Future Generations Act (Welsh Government, 2015), which are independent of policies in England and other UK nations. These devolved powers and subsequent differences mean that it cannot, and should not, be automatically assumed that health outcomes and health research will be the same across UK nations. We simply do not know if the outcomes will be similar. Thus, it is vital to not simply generalise research findings from other UK nations. Specific studies of Welsh populations are crucial.

The Welsh Government has introduced measures to assess the overall success and health outcomes of births in Wales. This includes the assessment of 'healthy' births (Welsh Government, 2021). Here, births are excluded from being defined as healthy if the following criteria are met: labour onset is not spontaneous, labour is augmented, mode of delivery is caesarean section, delivery involves the use of forceps or ventouse, the gestational age is < 37 weeks, it is a still birth, epidural is used or severe perineal trauma or episiotomy is recorded, the birth is considered high birthweight (HBW) or low birthweight (LBW), there is significant blood loss or if there is a low five minute APGAR score. Worryingly, utilising this criteria meant that in 2020 only 23% of births were considered healthy, a rate that has remained relatively stable since 2016 (Welsh Government, 2021). Consequently, it is of vital importance that pregnancy outcomes in Wales are improved.

In light of these statistics, the Welsh Government have introduced programmes to attempt to improve outcomes. This includes the All Wales Breastfeeding Five Year Action Plan (Welsh Government, 2019a) which utilises a health system, population level and whole system approach to improve breastfeeding rates in Wales. However, this does not incorporate pregnancy environment related determinants, as will be discussed later in the thesis. Additionally, the Healthy Child Wales Programme (Welsh Government, 2016) has been implemented. This programme was developed as an all-Wales approach to support and improve child development, health and welfare up to the age of seven years. It aims to bring together local authorities, health boards, communities, education and third sector organisations to achieve these aims. However, unfortunately, with the exception of a target focusing on ensuring antenatal care is booked by 10 weeks gestation, there is no mention or consideration of the importance of pregnancy. Thus, the current programmes do not specifically address the importance of pregnancy or attempt to improve the pregnancy environment, despite the influence this can have on both maternal and infant short and long term outcomes.

1.1.3. Health behaviours in pregnancy

It has been highlighted that the environment during pregnancy can have long lasting implications. One such environmental influence during pregnancy is the mothers health behaviours. Health behaviours refer to the actions an individual may undertake that either positively or negatively affect their health or mortality (Short and Mollborn, 2015). These can include, and indeed this thesis will focus on the behaviours of smoking, alcohol consumption, exercise and diet. Health behaviours are a key environmental influence to explore due to their potentially modifiable nature. This allows them to be targeted for potential behavioural interventions to improve both pregnancy and longer term outcomes for both mother and child (Gaillard et al., 2019).

Pregnancy is an ideal period in which to promote positive health behaviours. It is a period in which women are often highly motivated to improve and change behaviours (Kominiarek and Peaceman, 2017, Crozier, 2009a). However, it is also vital that no blame is placed upon women should they be undertaking health behaviours perceived to be negative (Stacey et al., 2022). Moreover, motivation to improve behaviour is not necessarily sufficient to enable behaviour change. A prominent behaviour change model, the COM-B model (Michie et al., 2011), proposes that behaviour is a product of not only motivation, but also capability and opportunity. Indeed, behaviour change relies upon the successful interaction of these three factors. Consequently, it is vital that pregnant women receive appropriate guidance, information, support or perhaps interventions to influence their health behaviours (Olander et al., 2018).

Women typically receive advice and guidance on appropriate health behaviours in pregnancy during either, their first contact appointment with a doctor after becoming aware of the pregnancy, or at their antenatal booking appointment with a midwife. Indeed, it is typically midwives that are relied upon within the health system to confer guidance. However, research has identified that midwives have limited time available in appointments to address this important topic and often lack the training and confidence to support improvement in these behaviours (Sanders et al., 2016). Moreover, whilst all women should perhaps be offered guidance and advice, or simply the necessary information to make informed decisions, often this is not the case. For example, in the health service often the advice a woman receives on health behaviours during antenatal care differs depending on a woman's weight or body mass index (BMI), despite it being beneficial to all (Avery, 2018, Hardy et al., 2014, Bye, 2016). Thus, although the health service may appear to be the ideal environment within which to address health behaviours in pregnancy, improvements in the understanding of health behaviours and how guidance is delivered is important.

The following sections will outline the current state of knowledge regarding the selected health behaviours in pregnancy. It will then outline the evidence regarding the influence of these health behaviours on a range of maternal and infant outcomes.

1.1.3.1. Smoking

Tobacco smoke is extremely harmful, containing more than 7000 toxic compounds and chemicals (Benjamin, 2011). Current NICE guidelines recommend abstaining from smoking in pregnancy, or at least reduce the levels of smoking if cessation is not possible (The National Institute for Health and Care Excellence, 2019). Women who report smoking during their initial general practitioner appointment or booking appointment typically with a midwife, may be directed to smoking cessation services and should be advised to quit at every available opportunity (Hardy et al., 2014). An extensive systematic review and meta-analysis covered 30 years of research into the global prevalence of smoking in pregnancy (Lange et al., 2018). Overall, time trend analysis identified that the prevalence of smoking in pregnancy has decreased over this period. The overall global smoking prevalence was estimated to be 1.70%. However, within the European region the rate was estimated to be 8.10%, whilst in the UK it was 23.30%, despite the clear guidance from NICE. It should be noted however, that the prevalence may be inflated due to the decreasing time trend. A more recent meta-analysis of specifically cross-sectional studies from around the world identified 234 eligible articles, from which it was determined that the overall prenatal smoking prevalence was 12% (Restivo et al., 2020).

It is also possible for prevalence to vary when considering different regions of the UK. Indeed, compared to the UK prevalence previously highlighted, Orton (2014) identified a smoking prevalence rate of 57.40% after collecting data from two maternity hospitals in Nottingham, England. When considering Wales, a recent annual report (Welsh Government, 2021) identified that the prevalence of smoking in pregnancy in Wales has decreased slightly in recent years from 18.40% in 2016, the first year of comparable data, to 17% in 2020, as recorded in the initial antenatal appointment. It was also noted that 17% were recorded as smoking at delivery, indicating smoking rates remain stable across pregnancy in Wales. Research has also indicated that women who continue to smoke in pregnancy show a general trend of reducing their rate of smoking as it is believed it will minimise or eliminate the associated risks for the baby, however it is known there is no consumption without risk

(Inoue-Choi et al., 2017). Given that guidance is to abstain from smoking where possible, this high rate is a cause for concern.

Research has been undertaken to gain an understanding of the risk factors for smoking during pregnancy. Identified risk factors have included education level, employment status, socioeconomic status, income, marital status, parity, unplanned pregnancy and lower age (Suzuki et al., 2010, Madureira et al., 2020, Míguez et al., 2019, Balwicki et al., 2016, Orton, 2014, Smedberg et al., 2014, Krstev et al., 2012, Maxson et al., 2012, Míguez and Pereira, 2018, Kaneko et al., 2008). However, the risk factors for smoking in Wales are poorly understood.

1.1.3.2. Alcohol

In previous years, UK guidance advised women to abstain from consuming alcohol whilst attempting to conceive and during the first trimester, but also indicated that women should consume no more than one to two units, once or twice a week. This guidance was often deemed inconsistent and confusing for health professionals and pregnant women (Mamluk et al., 2017). Consequently, in 2016 the UK Chief Medical Officers commissioned the first review of alcohol guidance since 1995. Following an extensive review, it was concluded that the effect of low level alcohol consumption in pregnancy was unclear, due to inconsistent findings and a paucity of research and as such it was safer to abstain from consuming alcohol whilst planning to become pregnant or at any point in pregnancy (Department of Health, 2016). This conclusion was supported by a systematic review and meta-analysis (Mamluk et al., 2017), which cautioned there were potentially no ‘safe’ levels of alcohol consumption in pregnancy and that the original guidance should be changed. Consequently, the UK guidance was updated and the National Institute for Health and Care Excellence (NICE) now recommends that women should abstain from alcohol during this period (The National Institute for Health and Care Excellence, 2019). This guidance has been adopted in more than 45 other countries worldwide (Halliday et al., 2017).

Despite this updated guidance recommending abstaining from alcohol consumption, the prevalence of alcohol consumption in pregnancy reflects different behaviour patterns. Here, prevalence refers to any reporting of women consuming alcohol during pregnancy. In a systematic review and meta-analysis (Popova et al., 2017), whilst the global prevalence of alcohol consumption in pregnancy was found to be 9.80%, the UK worryingly had one of the highest rates, significantly above this level at 41.30%. This is supported by a large cross-sectional study involving 15 European countries (Mårdby et al., 2017). This study identified an overall prevalence of alcohol consumption in pregnancy in these European countries of 15.90%. However, when considering specific regions, Western Europe (UK, Italy, Switzerland, France, Austria and Netherlands) had higher rates than Eastern or Northern Europe, and within this region the UK had the highest rate at 28.50%. There is only limited data on alcohol consumption in pregnancy available in Wales, however data from the 2010 Infant Feeding Survey suggested a prevalence of 35% (McAndrew et al., 2012). Clearly, alcohol consumption in pregnancy in the UK is worryingly high.

Research has been undertaken to understand that factors that predict alcohol use in pregnancy, however this research is often contradictory (Corrales-Gutierrez et al., 2020). Overall, factors that have been suggested to influence alcohol consumption include employment status, education level, socioeconomic status, unplanned pregnancy, being single, smoking both pre-pregnancy and during pregnancy, age, BMI, parity (Mårdby et al., 2017, Stanesby et al., 2018, McCormack et al., 2017, Mallard et al., 2013, Murphy et al., 2013, O'Keeffe et al., 2015, Corrales-Gutierrez et al., 2020, Popova et al., 2021). Here, and throughout the thesis, parity refers to the number of children a woman has delivered. Depending on the research parity may be presented as a continuous number or referred to as nulliparous, if a woman has no previous deliveries, or multiparous, should there be previous deliveries. No research has been identified that investigated predictors of alcohol consumption in Wales. Regarding the consequences of alcohol, the effects of heavy alcohol consumption in pregnancy are well established. Heavy consumption is known to cause Fetal Alcohol Syndrome, which is associated with growth deficiencies, developmental delays and facial anomalies (Jones and Smith, 1975). However, the effect of lower levels of alcohol consumption is less well understood and will be the focus of this thesis.

1.1.3.3. Exercise

NICE also offer guidance relating to exercise in pregnancy in the UK. The guidance recommends that women should continue or start moderate exercise in pregnancy, ideally undertaking 150 minutes of moderate exercise per week, however certain vigorous sports associated with increased risk to the baby are discouraged (The National Institute for Health and Care Excellence, 2019). This guidance is similar in many countries internationally (Evenson et al., 2014). However, despite this guidance, evidence suggests that women typically decrease their physical activity levels when pregnant and few women meet the recommended exercise levels (Fell et al., 2009, Gaston and Cramp, 2011, Coll et al., 2016). Additionally rates vary greatly between countries. Gjestland et al. (2013) found that in

Norway, only 14.60% of participants achieved the exercise guidance, whilst a study in Brazil identified that 20.10% met the criteria (Nascimento et al., 2015). Two studies conducted in Spain identified levels of 22% and greater than 50% respectively (Baena-García et al., 2021, Román-Gálvez et al., 2021), whilst in Dublin in Ireland only 21.50% met the recommendations in early pregnancy (Walsh et al., 2011). One UK cohort study identified that 48.80% of participants reported undertaking exercise at 18 weeks, with this rate remaining similar at 32 weeks (Liu et al., 2011). However, rather than defining exercise according to the guidance, this study defined exercise as an activity sufficient to cause sweating for three or more hours per week. It was not possible to identify any studies that have investigated the prevalence of exercise in pregnancy in Wales, and given the highly variable rates it is important that this evidence is established.

Factors associated with undertaking exercise in pregnancy, albeit at times in contradictory directions of effect, include marital status, employment status, income, education level, socioeconomic status, parity, BMI , smoking and diet (Baena-García et al., 2021, Román-Gálvez et al., 2021, Gaston and Cramp, 2011, Nascimento et al., 2015, Liu et al., 2011, Amezcua-Prieto et al., 2013, Bedrick et al., 2020). However, as with the health behaviours previously discussed, no evidence has been identified that has investigated factors influencing exercise in pregnancy in Wales.

As will be highlighted and discussed throughout this chapter in relation to the influence of prenatal exercise on a range of outcomes, there are certain limitations relating to the existing literature. Typically, research assesses exercise in pregnancy at only one timepoint. Whilst this provides useful data it would be preferential to assess exercise at multiple timepoints longitudinally across pregnancy, as there are physical barriers to undertaking exercise with increasing gestation, such as discomfort. Additionally, traditionally the method for assessing exercise has been self-report, whether via validated questionnaire or simpler individual questions. As will be discussed later in Chapter Two, self-report can be accompanied by inherent biases and inaccuracies. Only recently has research begun to utilise more objective assessments, such as activity trackers, thus potentially providing more accurate data. It is possible that this difference in methodology could influence findings and perhaps alter the direction and strength of association patterns identified in the literature reviews. Finally, many studies relevant to this chapter do not extensively assess the type of exercise or the degree of exercise undertaken, which may provide less accurate findings in comparison to more comprehensive assessments. These factors will be relevant to all studies in all fields of research investigating the influence of exercise, however they should be kept in mind when considering the existing literature presented within this thesis.

1.1.3.4. Diet

In the UK, NICE offers guidance on maternal diet during pregnancy (The National Institute for Health and Care Excellence, 2014). This includes advice on food hygiene and specific foods that should be avoided whilst pregnant. Moreover, it highlights the importance of a healthy balanced diet that contains at least five portions of fruit and vegetables per day as well as one portion of oily fish per week. It also recommends the use of daily supplements for vitamin D and folic acid, whilst emphasising that calorie intake should not increase in the first six months and should only increase by 200 calories per day in the third trimester, thus dispelling the “eating for two” myth. This information is also offered by the NHS (NHS, 2020).

1.1.3.4.1. Measuring diet

Traditionally, research investigating diet has focused on examining individual dietary components. However, it has been argued that this offers limited insight. In recent years it has been widely acknowledged that a person’s diet is highly varied, consisting of a complex interaction of a range of different food groups and nutrients. Diet is rarely comprised of single dietary components consumed in isolation. Focusing specifically on individual nutrients may oversimplify this relationship and cannot account for or begin to address extensive intercorrelations and interactions between food groups (Chen, 2016, Hu, 2002, Newby and Tucker, 2004, Cespedes and Hu, 2015).

Whole diet approaches, which provide an overall view of diet, overcome these issues and are argued to more accurately predict health outcomes (Loy and Jan Mohamed, 2013a). One method to examine overall diet is via dietary patterns, which are being increasingly utilised within research (Loy and Jan Mohamed, 2013b, Hu, 2002, Newby and Tucker, 2004). The use of dietary patterns is supported by nutritional intake evidence, which has demonstrated that dietary patterns adequately characterise dietary intake and thus are a valid measure (Northstone et al., 2008, Freitas-Vilela, 2017). Dietary patterns at the population level have been shown to be stable over time, with patterns replicated with minimal variation (Crozier, 2009b). It has also been demonstrated that dietary patterns change little from pre-pregnancy to pregnancy and even to the postpartum period up to four years (Crozier, 2009b, Northstone and Emmett, 2008).

Dietary patterns can be derived *a priori* or *a posteriori* (Moeller et al., 2007, Cespedes and Hu, 2015). *A priori* methods assess the degree to which a participants diet aligns with pre-defined dietary patterns, indices or concepts of desirable eating habits, based on previous scientific and nutritional knowledge or guidelines and recommendations (Moeller et al., 2007, Newby and Tucker, 2004). *A priori* outcomes include the popular Mediterranean diet score and the Healthy Eating Index (Kennedy et al., 1995). In contrast, *a posteriori* techniques are data driven, deriving patterns empirically from observed dietary data, clustering related food groups that are consumed together using data reduction (Fransen et al., 2014, Newby and Tucker, 2004). Consequently, patterns derived from this method are typically a more accurate reflection of the actual diet consumed by a population and will be the focus of this thesis.

Dietary data are typically obtained utilising 24-hour recall, food diaries or food frequency questionnaires (FFQ). Whilst research has shown that similar dietary patterns can be derived utilising the different methods (Loy and Jan Mohamed, 2013a, Crozier, 2008) the use of FFQs can provide a longer term view of diet and as such may better represent habitual dietary intake compared to other methods (Thompson et al., 2010). Moreover, FFQ's are typically the method utilised in cohort studies as they require less time to complete, are cheaper to administer and are more accessible to the general population than food diaries which have been associated with poor return rates (Crozier, 2008, Loy and Jan Mohamed, 2013a).

The most commonly utilised data analysis methods to derive *a posteriori* dietary patterns are principal component analysis (PCA) and cluster analysis (Freitas-Vilela, 2017). PCA is a variable centred form of factor analysis which identifies common underlying patterns of food consumption, correlating food groups and provides each participant with a summary score for each extracted dietary pattern. Alternatively, cluster analysis is person centred, separating participants into exclusive and non-overlapping groups who consume similar food groups (Freitas-Vilela, 2017, Hu, 2002). Whilst both methods have been found to identify similar dietary patterns, PCA is often considered advantageous due to the continuous nature of the scores which may be more informative compared to the dichotomy of cluster analysis (Crozier et al., 2006, Freitas-Vilela, 2017).

1.1.3.4.2. Types of dietary patterns

Dietary patterns have been identified in a range of populations including in pregnancy. A number of studies investigating this in the UK have been undertaken. Northstone et al. (2007) conducted an early investigation into dietary patterns in pregnancy utilising the Avon Longitudinal Study of Parents and Children (ALSPAC) cohort. Utilising PCA, five dietary patterns in pregnancy were identified: Health Conscious, Traditional, Processed, Confectionary and Vegetarian. Health Conscious was defined by high intake of fruit, salad, rice, pasta, cereals, eggs, pulses, fish, fruit juice, white meat and non-white bread. Traditional consisted of high intake of all types of vegetables, red meat and poultry. Processed comprised of high fat processed foods and Confectionary of snack foods with high sugar content. Finally, Vegetarian had high intake of meat substitutes, nuts, pulses, and herbal tea and low intake of meat and poultry. Research from the Southampton Women's Survey, identified the patterns labelled Prudent and High Energy (Crozier, 2009b). The UPBEAT cohort found Fruit and Vegetables, African/Caribbean, Processed, and Snack dietary patterns (Flynn, 2016b). Similarly, Marvin-Dowle et al. (2018) utilised data from the Born in Bradford cohort and identified three dietary patterns: Snack and Processed Foods, Meat and Fish, and Grains and Starches.

Dietary patterns in pregnancy have been identified in many countries including, Holland (Tielemans et al., 2015) Poland (Wesołowska et al., 2019), Spain (Cucó et al., 2006), Greece (Chatzi et al., 2017), Denmark (Rasmussen, 2014), Norway (Englund-Ögge et al., 2018), Finland (Arkkola et al., 2008), America (Starling et al., 2017) and New Zealand (Thompson et al., 2010). Dietary patterns will naturally vary between populations due to the data driven nature of *a posteriori* methods. This is particularly true between countries with different traditional diets. However, whilst the labelling of patterns and food groups that make up the patterns may differ, there are generally underlying similarities throughout. For example, all dietary patterns regardless of specific differences can be labelled overall as either healthy or unhealthy and thus comparisons between countries can be made.

Research has suggested that dietary patterns may be influenced by a variety of factors. This includes socioeconomic status, education, parity, employment status, maternal age, BMI, smoking status and levels of physical activity (Marvin-Dowle et al., 2018, Northstone et al., 2007, Arkkola et al., 2008, Hoffmann et al., 2013, Bedrick et al., 2020). However, with the exception of a paper published as part of this thesis (Garay et al., 2019), no previous studies have investigated dietary patterns or their determinants in a pregnant population in Wales.

1.1.4. Co-occurrence of health behaviours

Health behaviours rarely occur independently of each other, instead the tendency to cluster has been noted. Indeed, suboptimal behaviours such as smoking, consuming alcohol, poor diet and sedentary behaviour are generally related, clustering and occurring together. The same is also true for healthier behaviours (Gaillard et al., 2019, Cano-Ibáñez et al., 2020, Bird et al., 2017) and they are all part of a larger pattern of health related behaviours (Shin et al., 2016). For example, Coathup (2017) utilising data from the ALSPAC cohort in the UK, identified that an unhealthy processed dietary pattern was associated with heavy alcohol consumption, whilst healthier dietary patterns were associated with light to moderate alcohol use. The authors also replicated this study by utilising a contemporary population, as initial ALSPAC data collection occurred over 20 years previously, and again identified that lower alcohol consumption was related to healthier dietary patterns in pregnancy (Coathup et al., 2017). Additionally, heavy smoking has been found to be associated with heavy alcohol intake in pregnancy in the UK (O'Keeffe et al., 2015), alcohol consumption with smoking in Canada (Popova et al., 2021), an unhealthy dietary pattern with smoking in Denmark (Knudsen, 2008) and an unhealthy dietary pattern with both smoking and exercise in Spain (Cucó et al., 2006). In light of the clear co-occurring nature of health behaviours it becomes vital to consider the potential influence of health behaviours on maternal and infant outcomes simultaneously rather than independently. However, this rarely represents the reality of the existing research that has been conducted (Bird et al., 2017).

1.1.5. The influence of maternal health behaviours in pregnancy

As previously highlighted, the in-utero environment during pregnancy may influence the lifelong health and development of both mother and child. Maternal health behaviours are one such environmental influence, however the effect of these behaviours is often poorly understood. This section will now outline the current understanding of the influence of the selected health behaviours in pregnancy on a range of maternal and infant outcomes.

1.1.5.1. Maternal outcomes

1.1.5.1.1. Gestational weight gain

Gestational weight gain (GWG) refers to the weight a woman gains during pregnancy, calculated using the pre-pregnancy weight and weight at delivery. In a pregnancy characterised by GWG of 11 kg at 40 weeks, 35% of the overall GWG is comprised of the placenta, fetus and amniotic fluid (Pitkin, 1976). Whilst GWG is healthy, expected and generally a positive sign of pregnancy progression and fetal growth (Ahluwalia, 2015, Fealy et al., 2020), there is an optimum recommended range. Guidelines exist regarding recommended levels of GWG, with the Institute of Medicine (IOM) updating their existing guidelines in 2009 to incorporate maternal pre-pregnancy BMI as defined by the World

Health Organisation (WHO) (Institute of Medicine, 2009). These guidelines are outlined in Table 1.1. GWG outside of the recommended guidelines is associated with a range of poor outcomes for both mother and infant. Research suggests that excessive GWG is associated with higher risk of gestational hypertension, gestational diabetes, augmentation of labour, caesarean section (CS) delivery, postpartum weight retention, large for gestational age (LGA) infants and macrosomia as well as childhood obesity (Crane et al., 2009, Siega-Riz et al., 2009, Campbell et al., 2016, Nehring et al., 2013, Tie et al., 2014, Mamun et al., 2014, Kominiarek et al., 2018, Wu et al., 2020, Baugh et al., 2016). Conversely, inadequate GWG has been linked to increased risk of low birthweight, small for gestational age (SGA) infants, preterm birth and infant admittance to intensive care units (Goldstein et al., 2017, Kominiarek et al., 2018, Bird et al., 2017, Baugh et al., 2016).

Table 1.1 The current Institute of Medicine guidelines on GWG by pre-pregnancy BMI

BMI	Recommended GWG (kg)
Underweight (< 18.5)	15.5 - 18
Healthy (18.5 - 24.9)	11.5 - 16
Overweight (25 - 29.9)	7 - 11.5
Obese (> 30)	5 - 9

The guidelines and recommended weight gain ranges were developed on the basis that they were most consistently associated with good pregnancy outcomes in America. However, there are several critiques of these guidelines (Gluckman et al., 2014, Beyerlein et al., 2010, Mardones et al., 2021). The guidelines are broad, especially considering the range of BMI and weight gain possibilities within the same category. For example, a woman at the low end of the healthy BMI category could gain only the minimal recommended weight (11.5 kg), whilst a woman at the top end could gain the maximum weight (16 kg). Both are within the healthy recommended range however this weight gain could lead to very different outcomes. Additionally, the guidelines are based on the WHO BMI classifications, which in themselves are considered problematic, but also these classifications are based on non-pregnant adult populations. As such, they may not reflect BMI conditions in pregnancy. Furthermore, the IOM guidance is based on American data and reflect Western opinions on weight and consequently it may not be directly generalisable to other ethnicities, counties and socioeconomic levels where healthy BMI ranges and health behaviours differ. Finally, there is suggestion that the guidance may only be truly appropriate for women in the underweight and healthy weight BMI categories, as evidence suggests that the recommended weight gain in obese and overweight women may in fact lead to increased suboptimal outcomes such as higher risk for gestational diabetes , low birthweight infants and pre-term birth (Beyerlein et al., 2010). Despite these critiques, the IOM guidance remains a useful tool for assessing weight gain in pregnancy, however this should be considered in relation to any findings.

Despite this available guidance and the poor outcomes associated with GWG outside of the recommended range, GWG in populations often differs. In a large systematic review involving over one million participants worldwide only 30% of women gained the recommended weight during pregnancy, with 23% and 47% instead having inadequate or excessive GWG respectively (Goldstein et al., 2017). Worryingly, there are also indications that the prevalence of excessive GWG is increasing (Gavard and Artal, 2014). Upon investigation, it was not possible to identify any existing studies examining either the prevalence or risk factors associated with GWG in the UK. This is a concerning oversight as during the previous 30 years, regular weighing and tracking weight across pregnancy has not been encouraged (Allen-Walker et al., 2015). Instead NICE recommends a women is weighed only at the booking appointment (NICE, 2010), despite research identifying that women do not express barriers to being weighed during pregnancy (Swift et al., 2016). This differs to other countries such as America where GWG is regularly monitored throughout pregnancy (Kominiarek and Peaceman, 2017). Indeed, whilst NICE recommends that pregnant women, especially those with high BMI, receive at least brief guidance on physical activity and diet during antenatal appointments, there is no specific emphasis on GWG (NICE, 2010, Avery, 2018). Moreover, research has identified that, in the UK, pregnant women were generally unconcerned about GWG, with the suggestion that this was in part related to a lack of guidance from health professionals who were also unclear about GWG advice (Olander et al., 2011).

Regarding factors that affect GWG outcomes, there is a strong consensus in the literature that maternal BMI influences GWG (Heery et al., 2015, Kowal et al., 2012, Morisset et al., 2017, Yu et al., 2021, McDonald et al., 2020). Other risk factors that have been identified include socioeconomic status, education, maternal age, hypertension and parity (Fealy et al., 2020, Restall et al., 2014, Deputy et al., 2015, Kowal et al., 2012, Campbell et al., 2016, Chasan-Taber et al., 2008, Brawarsky et al., 2005, Fraga and Theme Filha, 2014). After observing the lack of studies considering the prevalence or biopsychosocial risk factors for GWG in the UK, research was undertaken during this PhD to investigate this. This research utilising the Grown in Wales cohort identified risk factors for GWG including prenatal symptoms of depression, maternal BMI and income (Garay et al., 2021). The current state of knowledge regarding the influence of health behaviours on GWG outcomes will now be examined.

1.1.5.1.1.1. Smoking

When considering the influence of health behaviours on GWG outcomes, an examination of the current literature on the effect of smoking highlights highly inconsistent findings. For example, Amyx et al. (2021) conducted a large multicentre study in France of 24,850 participants and identified that smoking, or quitting smoking during pregnancy was associated with increased risk of inadequate GWG. However, it should be noted that France has a significantly higher rate of smoking in pregnancy than many other countries, as acknowledged by the authors, which may have influenced results. Nevertheless, Lindberg et al. (2016) found similar results regarding smoking in pregnancy in research conducted in Wisconsin, America. On the other hand, the majority of research has reached different conclusions. Research such as that conducted by Restall et al. (2014) in New Zealand, identified that women who stopped smoking by 14 to 16 weeks gestation had an increased risk of excessive GWG. This was supported by research utilising data from the 2010-2011 Pregnancy Risk Assessment Monitoring System (PRAMS) cohort covering a range of states across America, which also linked smoking cessation to excessive GWG (Deputy et al., 2015). However, in contrast, research conducted in Australia, Rotterdam, Poland and even a study utilising earlier data from the PRAMS cohort, identified either no association between smoking and GWG (Fealy et al., 2020, Wells et al., 2006, Suliga et al., 2018) or identified that smoking increased the risk of excessive GWG (Gaillard et al., 2013). As with much of the research that will be discussed within this thesis, the body of literature suffers from heterogeneity. For example, studies measure smoking at different timepoints during pregnancy, ranging from first trimester to third trimester, or the whole of pregnancy. This could be one of the factors contributing to the inconsistency of findings in this area. Consequently, the nature of the association between smoking in pregnancy and GWG is unclear with further research, not just in Wales but in the UK in general, required to elucidate this relationship.

1.1.5.1.1.2. Alcohol

There appears to be only limited previous research that has examined the influence of consuming alcohol in pregnancy on GWG outcomes. It was noted that studies investigating a wide range of predictors for GWG often neglect to incorporate prenatal alcohol consumption. Indeed, a recent in depth review investigating health behaviour interventions on a range of maternal outcomes identified no intervention studies focusing on alcohol consumption (Hayes et al., 2021), surprising given the modifiable nature of this behaviour. Of the limited research that has incorporated alcohol use, it appears that there is no association between prenatal alcohol consumption and GWG. The research identified was previously highlighted in relation to smoking and GWG outcomes, with studies utilising data from different time ranges within the PRAMS cohort in America (Wells et al., 2006, Deputy et al., 2015), and from the Generation R cohort in Rotterdam (Gaillard et al., 2013). These studies considered alcohol consumption at any point in pregnancy, rather than focusing on levels or dose response, and measured this at similar timepoints. Whilst these are the only studies identified that have considered the effect of alcohol, the large participant numbers within both studies and the comprehensive adjustment for potentially confounding variables, indicates this may be compelling evidence. Nevertheless, further research is required to enhance the current understanding of this area.

1.1.5.1.1.3. Exercise

There has been sizable focus in the literature on the influence of prenatal exercise on GWG outcomes. DiPietro et al. (2019) conducted an umbrella review, which is a review of systematic reviews and meta-analyses, investigating the influence of undertaking exercise in pregnancy on a range of maternal outcomes. Regarding GWG, the authors concluded that there was strong evidence that physically active women in pregnancy gained less weight overall and had reduced risk of excessive GWG, although evidence regarding a potential dose-response was limited. In this review ‘physically active’ was defined as those meeting the recommended guidance of 150 minutes per week of moderate intensity exercise. It should be highlighted that the studies within the review consisted largely of randomised control trials (RCTs), reflective of the overall literature in this area which is dominated by intervention studies. Indeed, further systematic reviews were identified within this area also focusing on RCT studies and reassuringly they reach similar conclusions (Bernabé et al., 2018, Ruchat et al., 2018, Vargas-Terrones et al., 2019b, Wang et al., 2019). However, it should be noted again that the existing studies were highly heterogeneous regarding definitions and measures of exercise, outcomes and pregnancy populations.

RCT studies provide evidence for the effect of specific, often intensive, exercise interventions. However, these controlled studies may not reflect the ‘real world’ influence of women’s typical exercise behaviour during pregnancy. As such, evidence from observational studies comprising of typical pregnancy participant populations are important to fully understand the influence of exercise. Harris et al. (2015) utilised data from 850 participants within the South Carolina component of the PRAMS cohort. They identified that women undertaking exercise three or more times per week were more likely to meet GWG recommendations that those undertaking less exercise. This therefore strengthens the evidence of a beneficial effect of exercise on GWG. This is supported by Gimunová et al. (2018), who utilised data from the European Longitudinal Study of Pregnancy and Childhood (ELSPAC) and also identified that exercise during pregnancy was associated with decreased GWG. However, there is research with contrasting findings. Chasan-Taber et al. (2014) utilised data from a large cohort of 1276 Hispanic participants in Massachusetts, America. Unlike many other studies, Chasan-Taber et al. (2014) utilised an in-depth validated exercise questionnaire that assessed various types of physical activity in detail, rather than simply reporting on overall general physical activity in pregnancy. Here, no association was identified between intensity or type of physical activity during either early, mid or late pregnancy and GWG. As such, despite the evidence from RCTs, the influence of typical exercise behaviours in pregnancy populations on GWG needs to be better understood.

1.1.5.1.1.4. Dietary patterns

The evidence for the influence of dietary patterns in pregnancy on GWG appears to be inconsistent. Some studies identify that only healthier dietary patterns affect GWG. For example, Cano-Ibáñez et al. (2020) in a Spanish population identified that a Mediterranean dietary pattern moderately reduced GWG, whilst there was no association with an unhealthy Occidental dietary pattern. Similarly, Suliga et al. (2018) in a study mentioned previously in relation to smoking, also identified that high adherence to a healthy Prudent dietary pattern decreased the risk of excessive GWG in a Polish population, but varied or unhealthy dietary patterns had no influence. However, research has also reached differing conclusions. One such study was that conducted by Shin et al. (2016), utilising the 2003-2006 National Health and Nutrition Examination Survey (NHANES), a nationally representative survey of children and adults in America. Here, authors demonstrated that only a Mixed dietary pattern, rather than Healthy or Western was associated with GWG outcomes. Indeed, the mixed dietary pattern not only lowered the risk of excessive GWG, but actually also increased the risk of inadequate GWG.

Literature has also identified that unhealthy dietary patterns increased GWG. Maugeri et al. (2019), utilising the Mamma and Bambino cohort in Italy identified that only a Western dietary pattern and not a Prudent dietary pattern, was associated with increased overall GWG.

It may be important to note however, that this study excluded participants recorded as having a CS delivery, which given that this is a potential risk factor for GWG outcomes as highlighted previously, may have influenced results. Nevertheless, studies utilising large participant populations of 3360 and 3374 from Finland (Uusitalo et al., 2009) and The Generation R cohort in Rotterdam (Tielemans et al., 2015) respectively, also identified that only unhealthy dietary patterns were associated with GWG. Specifically, within these studies, unhealthy dietary patterns increased either overall GWG or the risk of excessive GWG, although Tielemans et al. (2015) do note that the evidence is not compelling due to the weak association. The inconsistent nature of the evidence within this research area is further exemplified in a recent systematic review and meta-analysis by Abdollahi et al. (2021). This review investigated the association between dietary patterns in pregnancy and perinatal outcomes that included GWG. Dietary patterns from the 10 included studies were grouped as healthy, unhealthy or mixed. Abdollahi et al. (2021) stressed that there was insufficient data to investigate the association between the unhealthy or mixed dietary patterns and inadequate GWG. The only significant association identified was that a healthy dietary pattern increased overall GWG, however this association was indicated as weak and did not occur with excessive GWG. Importantly, it was determined that the quality of all incorporated studies was low or very low largely due to heterogeneity between studies, an issue which continuously arises, and a lack of adjustment for potential confounders. As such, the literature base for the influence of dietary patterns in pregnancy is highly inconsistent and further research is needed to understand the relationship.

1.1.5.1.1.5. Summary

Although there is clear guidance regarding the recommended GWG in pregnancy, the prevalence of excessive GWG is high. Regarding the influence of health behaviours, smoking in pregnancy is most consistently identified as influencing GWG outcomes, specifically increasing the likelihood of suboptimal results. However, the literature base on exercise, dietary patterns and alcohol consumption is at times highly inconsistent, with the alcohol literature base also suffering from a lack of evidence. Heterogeneity between studies is also frequently a cause for concern in this area. Moreover, prior to the research undertaken within this PhD (Garay et al., 2021), no research had been undertaken investigating the prevalence or predictors of GWG outcomes in the UK or Wales. In light of these factors, it is difficult to draw conclusions regarding the influence of maternal health behaviours in pregnancy on GWG outcomes and additional research is required.

1.1.5.1.2. Perinatal mental health

Mental ill health is among the most common morbidities relating to pregnancy, with an estimated one in five women developing mental health complications in pregnancy or the year following birth, known as the perinatal period (Howard et al., 2014). In the UK, perinatal mental health concerns are associated with an estimated cost to society of £8.1 billion per one year birth cohort, with 72% of this relating to adverse impacts on the child. This cost relates to productivity losses, health and social care service use, special educational needs and emotional difficulties (Bauer et al., 2014). Moreover, it is believed that between 40-70% of women have no access to specialist perinatal mental health services in the UK (Bauer et al., 2014). Depression and anxiety are the most prevalent mental health concerns in pregnancy (Rees et al., 2019) and are frequently comorbid (Sartorius et al., 1996, Heron et al., 2004). However it is generally accepted that prenatal depression and anxiety is underdiagnosed and undertreated (Goodman et al., 2014, Grigoriadis et al., 2013). Reports on the prevalence of prenatal depression and anxiety do vary, but anxiety has been identified as more common than depression (Martini et al., 2015, Fairbrother et al., 2016). A recent umbrella review identified that the global prevalence of antenatal depression ranges from 15-65% (Dadi et al., 2020), whilst the prevalence of prenatal anxiety appears to range from 15-25% (Field, 2017a, Dennis et al., 2017). When considering Wales, research utilising the Grown in Wales cohort that was worked upon during this PhD has previously reported a prevalence of prenatal depression and anxiety symptoms at term of 14.30% and 27.30%, respectively (Janssen et al., 2018). This is similar to another recent study conducted in Wales, with data analysis for this also conducted during this PhD, which identified a similar prevalence of prenatal depression and anxiety symptoms of 15.60% and 22.20% at booking, respectively (Savory et al., 2021). With the exception of these studies, no other research has investigated this in Wales.

Prenatal depression and anxiety have been associated with a range of suboptimal outcomes for both mother and child. In regards to the mother, studies have identified associations with outcomes that include pre-eclampsia, postnatal mental health and breastfeeding (Grigoriadis et al., 2019, Field, 2017b, Figueiredo et al., 2014, Acheampong et al., 2021, Rahman and Creed, 2007, Burt and Stein, 2002). In the child, prenatal depression and anxiety has been associated with outcomes that include pre-term birth, reduced gestational age, low birthweight (LBW) and SGA infants, reduced immunity, increased hospitalisation, internalising and externalising behavioural concerns, problems with social and emotional development, difficult temperament, poorer cognition, motor skills and language in early childhood (Rees et al., 2019, Grigoriadis et al., 2018, Field, 2017a, Rogers et al., 2020, Dadi et al., 2020, Jacques et al., 2019, Field, 2017b, Li et al., 2020, Eastwood et al., 2017). The evidence of an effect of maternal mental health into early childhood is also supported by research utilising the Grown in Wales cohort, with data analysis for this again conducted during this PhD. This research identified an association between prenatal mental health symptoms and both maternally reported and objective infant temperament and infant cognitive development (Savory et al., 2020).

These poor outcomes, the high prevalence, as well as the cost associated with both depression and anxiety, ensure that perinatal mental health is a major public health concern (Rees et al., 2019). Consequently, developing an understanding of the risk factors associated with maternal mental health is vital. Whilst the research in this area has typically focussed on depression rather than anxiety, factors that have previously been demonstrated to influence these outcomes include socioeconomic status, education level, social support, medical complications and a history of mental health difficulties (Bayrampour et al., 2018, Field, 2017b, Verbeek et al., 2019, Biaggi et al., 2016, Howard et al., 2014, Savory et al., 2021, Janssen et al., 2018, Furtado et al., 2018). There has also been research investigating the influence of prenatal maternal health behaviours, which will be discussed shortly. However, as with many other sections of this thesis, no research has investigated this area in Wales.

1.1.5.1.2.1. Smoking

There is a considerable body of evidence into the association of prenatal smoking on perinatal depression and anxiety. Although an early review concluded that there were inconsistent findings regarding smoking and maternal mental health (Lancaster et al., 2010), more recent reviews have highlighted that an association is present. Indeed, reviews by Maria de Jesus Silva et al. (2020) and Biaggi et al. (2016) demonstrated that overall prenatal smoking increased the likelihood of both depression and anxiety symptoms in pregnancy.

Specific studies that have investigated this area include an extensive study recently conducted by Ceulemans et al. (2021), who undertook a multinational study utilising data of 3907 pregnancy women from the UK, Ireland, The Netherlands, Norway and Switzerland. These researchers identified that prenatal smoking increased depressive symptoms measured by the Edinburgh Postnatal Depression Scale (EPDS) in pregnancy. However, there may be concern regarding the focus here on data collection during the peak of the current coronavirus pandemic, as this had the potential to influence findings by impacting on both behaviours and mental health. Nevertheless, that the findings follow the overall trend in the literature is reassuring.

Similarly, a study of 850 participants in Spain utilising the EPDS and State Trait Anxiety Inventory (STAI), determined that women who smoked during pregnancy had greater depression and anxiety symptoms than non-smokers and those who quit smoking in pregnancy (Míguez et al., 2019). Although this research utilised different high risk classifications to other studies, they also identified that women who smoked had stable levels of depressive symptoms across pregnancy, whilst the non-smoking participants had a decrease in symptoms from the first to the third trimester. Additionally, Fellenzer and Cibula (2014) utilised data from 18059 participants in America and identified that even low levels of smoking in pregnancy were associated with increased likelihood of mild, moderate and severe symptoms of depression. As with other sections of this chapter, this study also noted a dose response, where increasing levels of cigarette consumption per day were associated with higher levels of depressive symptoms. The use of an unusual, albeit validated measure of depression in this study, where participants rated their level of symptoms on a single five-point scale, also raises an issue with the literature area. As with the studies that will be discussed in relation to the other health behaviours of interest within this thesis, there is great heterogeneity between studies. In those discussed here, it is in relation to the measures of mental health as well as the scores utilised to classify participants as high risk. Whilst this does not lead to inconsistency in findings here, it is important to note the nature of the existing research. Moreover, as no research has been identified investigating this area in Wales despite the overall trend of a negative influence of smoking, our understanding of this area needs to be further enhanced.

1.1.5.1.2.2. Alcohol

The current body of research into the influence of prenatal alcohol consumption on maternal mental health is inconsistent in its conclusions and typically focuses on depression symptoms. Indeed, it was only possible to identify reviews in this area that have concentrated on prenatal depression. An early review by Lancaster et al. (2010) highlighted that there were inconsistencies in the association between prenatal alcohol consumption and prenatal depression, making an overall conclusion impossible. This was noted to be partly due to the heterogeneity between studies, an issue raised in the previous section. In contrast, a more recent review was identified that concluded that there was, in fact, a significant influence of prenatal alcohol on perinatal depression (Maria de Jesus Silva et al., 2020). However, the quality of this review appears to be poor as the evidence provided by this review is sparse. It contains very little information regarding the incorporated studies or explanation of how the conclusion was reached and fails to provide an assessment of the quality of the evidence. Thus, any conclusions drawn from this review should be treated with caution. Nevertheless some studies do support this conclusion. Coll et al. (2017) utilised the widely recognised EPDS to measure depressive symptoms in 4130 participants in Brazil and found that consuming alcohol in pregnancy increased depressive symptoms. Fellenzer and Cibula (2014) also reached a similar conclusion in a large study of 18059 participants in America, although they utilised a more unusual measure as noted in the previous section on smoking.

It is also possible that the direction of causality in this area may not be as expected. Indeed, it is entirely possible that rather than health behaviours influencing prenatal mental health, mental health may actual be influencing maternal prenatal health behaviours. As such, a limited number of studies have investigated if prenatal depression or anxiety predicts alcohol use in pregnancy. In America, trait anxiety as measured by the STAI has been related to greater alcohol use in pregnant women (Meshberg-Cohen and Svikis, 2007). Additionally, a UK based study that utilised data from the ALSPAC birth cohort provided a more thorough understanding through the collection of data throughout pregnancy (Leis et al., 2012). Researchers identified that whilst there was no association between high depressive symptoms and any alcohol use, there was a modest association between high anxiety levels and any alcohol use. Moreover, an association was identified between both high depression and anxiety at 18 weeks gestation and binge drinking at 32 weeks. Whilst a different direction to our focus, this research is still relevant to our understanding and important to consider.

In addition to studies linking prenatal alcohol with higher levels of depression, there is a significant body of research providing differing conclusions. Some studies, such as that by Waldie et al. (2015) in New Zealand and Silva et al. (2017) in Brazil found that a significant association between prenatal alcohol use and prenatal depression only existed at the univariable level. This significant association disappeared on incorporation into a multivariable model, therefore perhaps suggesting that other risk factors may be more heavily influencing depression. Moreover, other studies have identified no association between prenatal alcohol consumption and maternal mental health. Brittain et al. (2015) utilised data of 726 participants from the Drakenstein Child Health Study, a birth cohort in South Africa, and found no association between alcohol use in pregnancy and depression, when measured using the Beck Depression Inventory (BDI-II). Similarly, Alvik et al. (2006) in a Norway based study of 1749 participants using the Hopkins Symptom Checklist, identified no association between prenatal depression or anxiety and alcohol use in pregnancy, although again, this study investigates the relationship from the alternate direction. Clearly, the relationship between alcohol use in pregnancy and maternal mental health is not clear cut. As such, it is difficult to draw conclusions and further research is needed to improve the understanding within this area.

1.1.5.1.2.3. Exercise

There has been interest in the influence of prenatal physical activity on prenatal depression and anxiety. As with alcohol, there again appears to be relatively mixed findings, although the overall picture tends to support a positive influence. For example, some studies have found no influence of exercise. Coll et al. (2016) assessed this area in a cohort of 4130 pregnant women in Brazil and identified no association between leisure time physical activity and depression symptoms on the EPDS. However, this study did only measure physical activity in the previous week which may have limited the findings. Additionally, research utilising data on 1522 women in the UPBEAT cohort in the UK also did not identify a relationship between physical activity and depression in pregnancy (Wilson et al., 2020).

A variety of reviews have been undertaken of the literature in this area, covering both RCT and observational studies (DiPietro et al., 2019, Davenport et al., 2018a, Sánchez-Polán et al., 2021, Walsh et al., 2011, Kołomańska et al., 2019). Unfortunately, these reviews highlight the inconsistencies within this research area. Reviews by Walsh et al. (2011) and Sánchez-Polán et al. (2021) concluded that exercise during pregnancy was associated with reduced symptoms of prenatal depression and anxiety. This was supported by a comprehensive umbrella review conducted by DiPietro et al. (2019), however, it was strongly emphasised that the evidence was limited due to the few available studies. Conversely, another systematic review and meta analyses (Davenport et al., 2018a) identified that whilst prenatal exercise RCTs influence prenatal depression, there was no effect on symptoms of anxiety. This review added another level of complexity by stressing that it needed to be a high level of exercise which achieved the current guidance for this effect to be apparent, whereas a review by Kołomańska et al. (2019) concluded that even a small amount of exercise was effective in reducing depression.

Specific studies that indicate there is a relationship between prenatal exercise and perinatal mental health outcomes include that by Vargas-Terrones et al. (2019a). This research involved an exercise based RCT in Spain and found that this prenatal exercise reduced overall symptoms of depression. This is also demonstrated in studies of an observational nature. In Norway, women undertaking exercise one or two times per week were less likely to report depressive symptoms compared to those undertaking less exercise (Gjestland et al., 2013). Additionally, a survey of 520 women in Canada (Davenport et al., 2020) using the EPDS and STAI highlighted that participants who met the current physical activity guidance had significantly lower EPDS and state STAI scores than those undertaking less exercise. However, here it should be noted that this study focused on the current coronavirus pandemic, with data collected in April-May 2020, which may have influenced the findings. Overall, it may be safe to say that the current evidence base for the influence of alcohol consumption in pregnancy on perinatal mental health provides a complicated, unclear picture. Whilst it does appear that exercise may have a beneficial effect this needs to be confirmed.

1.1.5.1.2.4. Dietary patterns

As with the previous sections, the current evidence base for the influence of prenatal dietary patterns on perinatal mental health is full of inconsistencies. Some research has identified an influence of healthy dietary patterns. dos Santos Vaz et al. (2013) utilised data from the ALSPAC cohort and measured anxiety symptoms via the Crown-Crisp Experiential Index. Here, it was found that participants with the highest levels of adherence to Health Conscious and Traditional dietary patterns were less likely to have high anxiety symptoms than those with lower adherence. However, they also identified that participants with the highest adherence to the Vegetarian dietary patterns were more likely to have high levels of anxiety. This, therefore, perhaps suggests that a healthy but balanced diet may be required. Following a similar trend, a recent study in a large Chinese cohort of 17,430 participants also identified that healthier dietary patterns rich in dairy, nuts, fruit and vegetables reduced the risk of depression throughout pregnancy (Huang et al., 2021). Additionally, Miyake et al. (2018) in a Japanese population of 1744 participants determined that Healthy and Traditional Japanese dietary patterns were inversely associated with depression symptoms in pregnancy, but no association was found with the Western dietary pattern. This study utilised a less commonly utilised measure of depression, the Centre for Epidemiological Studies Depression Scale and collected data between the 5th and 39th week of gestation. However, it should be recognised that whilst this study is useful, the data collection across an extremely large range of timepoints in pregnancy may have influenced the findings.

Some studies have linked unhealthy dietary patterns to prenatal depression. Baskin et al. (2017) conducted a small study of 167 participants in Australia, utilising the EPDS to measure symptoms. This research found that an Unhealthy dietary pattern during pregnancy was associated with increased depressive symptoms, but there was no association with the Healthy dietary pattern. Similarly, albeit in the alternate direction due to the uncertainty regarding the direction of causality, a UK based study using ALSPAC data and the EPDS, identified that higher prenatal depression symptoms were associated with higher levels of unhealthy dietary patterns (Pina-Camacho et al., 2015).

These differences in the literature have been addressed in reviews. A systematic review and meta-analysis by Lai et al. (2014) concluded that healthy dietary patterns were associated with a decrease in depressive symptoms in pregnancy. They also identified that overall there was no association between Western dietary patterns and depressive symptoms, but acknowledged the existence of too few studies on this area for definitive conclusions. Similarly, a recent systematic review by Silva et al. (2019) on both depression and anxiety, concluded that Healthy dietary patterns were inversely associated with prenatal depression and anxiety and Traditional diets also reduced the risk of these symptoms. Again, due to the lack of literature and inconsistent findings there was no definitive evidence of an association between Western dietary patterns and perinatal mental health. It is important to note, however, that whilst all studies were considered of good methodological quality, the GRADE assessment indicated that the quality of evidence was very low due to design, small sample size and risk of bias. Thus, this may help explain inconsistencies in results and highlights that further research of improved quality is required in this area.

1.1.5.1.2.5. Summary

Perinatal mental health conditions such as depression and anxiety are common in pregnancy. Research in this area typically focuses on depression, rather than anxiety despite evidence suggesting a higher prevalence of anxiety. There is highly inconsistent evidence regarding the influence of alcohol consumption, exercise and dietary patterns in pregnancy on both prenatal depression and anxiety symptoms. Moreover, whilst smoking appears to have a negative influence, the literature typically only considers depression as an outcome. Consequently, further research is required to better understand the nature of this relationship.

1.1.5.1.3. Breastfeeding

Breastfeeding is a crucial behaviour that occurs between a mother and her child and is considered a vital component of maternal care. Breastfeeding provides a source of optimal infant nutrition, with breast milk being comprised of well-balanced essential nutrients, such as fatty acids, amino acids, lactose and water, as well as antibodies, growth factors and hormones (Martin et al., 2016, Picciano, 2001, Hamosh, 2001, Jensen and Lapillonne, 2009). Consequently, breast milk is considered to be superior to formula, which can only provide nutrients (Martin et al., 2016). Additionally, the skin-to-skin contact that naturally accompanies breastfeeding is important for developing a healthy bond between mother and infant (UNICEF UK, 2016). Breastfeeding has been associated with a range of outcomes for both mother and child. This includes reduced hospitalisation and decreased infant mortality, lower incidence and range of infections, but also improved cognitive, language and motor development, increased intelligence, improved mental health, reduced obesity in childhood and adolescence and reduced risk of diabetes in later life (Størdal et al., 2017, Anstey et al., 2016, Patnode et al., 2016, Leventakou et al., 2015, Hörnell et al., 2013, Boucher et al., 2017, Victora et al., 2016, Oddy et al., 2010, Dieterich et al., 2013). Additionally, in the mother breastfeeding has been associated with increased postpartum weight loss and reduced long-term risk of breast and ovarian cancers, diabetes and cardiovascular diseases (Victora et al., 2016, Dieterich et al., 2013, Chowdhury et al., 2015, Nguyen et al., 2019).

Research has indicated that whilst any amount of breastfeeding is more beneficial than no breastfeeding, the longer the duration the greater the benefits (Kramer and Kakuma, 2012). The WHO recommends that breastfeeding is initiated as soon as possible after birth, with exclusive breastfeeding continuing for a minimum of six months, followed by the introduction of breastfeeding supplemented with complementary foods for two years or longer (World Health Organisation, 2018). However, despite these recommendations, evidence suggests that the majority of women breastfeed for shorter periods of time worldwide (Victora et al., 2016). This influential review identified that on average only 37% of infants younger than six months of age are exclusively breastfed, whilst higher income countries have shorter breastfeeding durations than middle and lower income countries. Indeed, recent research by Bish et al. (2021) supports this, indicating that breastfeeding rates in many countries do not meet recommendations, with inconsistencies in trends over time. When considering European countries specifically, evidence suggests there are breastfeeding rates of 56-98% immediately after birth and 38-71% at six months, however when considering only exclusive breastfeeding this drops to 13-39% (Theurich et al., 2019).

Worryingly, a report by Steering (2016) has highlighted that breastfeeding rates in the UK are amongst the lowest in the developed world. In this report, four out of five women in the UK initiated breastfeeding, however there was a rapid decline within the first few weeks so that only 1% breastfed exclusively at six months. This rate meant that the UK had the lowest breastfeeding rate in the world at 12 months. Moreover, the report indicated that Wales had the lowest initiation and continuation rate in the UK. Indeed, Paranjothy et al. (2014) previously identified that while just over half of women in Wales initiate breastfeeding this rate declines promptly. In response to these extremely poor statistics the Welsh Government introduced the All Wales Breastfeeding Five Year Action Plan (Welsh Government, 2019a). This was developed to employ a health system, population level and whole system approach to improve levels of breastfeeding, however it is important to note that the plan did not target health behaviour determinants. Reassuringly, this plan has perhaps contributed to data indicating that breastfeeding rates at all postnatal timepoints in Wales were the highest on record in 2020 (Welsh Government, 2021). This routinely collected data, collected as part of the Healthy Child Wales Programme (Welsh Government, 2016), indicated that 63.50% of women initiated breastfeeding in 2020. Unfortunately, this rate still declined with 51.70% breastfeeding 10 days post birth, 37.40% six weeks postpartum and only 25.30% at six months. As such, despite Welsh initiatives it remains vital to improve breastfeeding rates in Wales.

It has been suggested that improving breastfeeding rates worldwide to the recommended levels could prevent the deaths of 823,000 children under five years of age every year (Victora et al., 2016). As such, it is vital to understand the factors that influence breastfeeding and this is an area of great research interest. A widely accepted predictor of breastfeeding outcomes is a woman's intention to breastfeed, and other suggested predictors include maternal education level, income, socioeconomic status, employment status, age, BMI, parity, mode of delivery and symptoms of depression (Callaghan et al., 2020, Henninger et al., 2017, Magnano San Lio et al., 2021, Bjørset et al., 2018, Dieterich et al., 2013, Lechosa-Muñiz et al., 2020, Craighead and Elswick Jr, 2014, Busck-Rasmussen et al., 2014, Bryanton et al., 2020, Wallwiener et al., 2016, Chih et al., 2021, Dias and Figueiredo, 2015, Griffiths et al., 2005, Amir and Donath, 2008, Häggkvist et al., 2010, Hobbs et al., 2016, Colombo et al., 2018, Logan et al., 2016, Bish et al., 2021, Arora et al., 2017, Apostolakis-Kyrus et al., 2013, Steering, 2016, Gallegos et al., 2020). There is also limited research that has been conducted specifically on Welsh populations which has identified that birth complications, socioeconomic status and maternal age influence breastfeeding outcomes in Wales (Welsh Government, 2021, Brown and Jordan, 2013, Brown et al., 2010). There has been less interest, however, in the influence of modifiable prenatal health behaviours on breastfeeding outcomes.

1.1.5.1.3.1. Smoking

Prenatal smoking is the health behaviour that has received the most research attention in regards to breastfeeding. The general trend in the literature appears to indicate that smoking is largely associated with suboptimal breastfeeding outcomes. This is emphasised in a systematic review and meta-analysis by Cohen et al. (2018), which considered a range of predictors of breastfeeding initiation and duration in developed countries. The review identified that despite some heterogeneity between studies, there was compelling evidence that smoking is a strong predictor of both breastfeeding initiation and duration. For example, when considering individual studies, early research was conducted in the UK utilising data from the popular ALSPAC cohort (Donath, 2004). This study demonstrated a strong negative association between maternal smoking in pregnancy and breastfeeding duration, with smokers being significantly less likely to be breastfeeding at six months compared to non-smokers. Indeed, this association remained when adjusting for breastfeeding intention, a known influential predictor of breastfeeding outcomes.

This finding is supported by a range of research from a variety of different countries, including Germany, America, Norway and Hong Kong (Wallwiener et al., 2016, Craighead and Elswick Jr, 2014, Häggkvist et al., 2010, Apostolakis-Kyrus et al., 2013, Leung et al., 2002). Recent research has further highlighted this association. Bish et al. (2021) undertook a large study of 7491 participants in Australia and found that those who smoked during pregnancy, which included current and past smokers, were less likely to initiate breastfeeding than those who did not smoke. However, this data are limited to the duration of the hospital stay and it is possible that participants may have initiated at a later date after leaving hospital, which would not have been considered. Similarly, in a study of 949 mother-infant dyads in a Spanish population (Lechosa-Muñiz et al., 2020), smoking in pregnancy was related to both decreased initiation of breastfeeding or breastfeeding at hospital discharge, as well as decreased duration of breastfeeding. Further support is provided by another study conducted with 2196 mother-infant dyads in Spain (Villar et al., 2018). Here, it was identified that non-smoking increased the likelihood of breastfeeding initiation, whilst smoking was linked to higher breastfeeding cessation levels.

Studies do identify alternative findings, although this is far less common. For example, a study of 860 participants in Australia found that smoking was only associated with breastfeeding before adjustment for confounding variables (Arora et al., 2017). It is possible that this finding is due to the nature of smoking behaviour, which is often linked to poorer sociodemographic environments, as discussed in previous sections, thus adjusting for this removes the association. As with other topics discussed in this thesis, it is possible there is a dose response influencing this relationship. Dennis (2002) identified that the more cigarettes a women smoked during pregnancy the less likely they were to initiate breastfeeding after birth. Nevertheless, overall the current literature suggests that prenatal smoking negatively influences breastfeeding outcomes. However, research is required in Wales to assess if the same pattern occurs here.

1.1.5.1.3.2. Alcohol

Unlike the literature on smoking, the evidence for the influence of prenatal alcohol consumption and breastfeeding outcomes is sparse. Instead, the research predominantly focuses on the effects of alcohol during the lactation period. Of the few studies that were identified, Arora et al. (2017) utilised data on 860 women in Australia to investigate a range of predictors on breastfeeding initiation. This research was previously highlighted in relation to smoking. Authors identified that participants who consumed alcohol during pregnancy were significantly less likely to initiate breastfeeding following birth. Whilst it is reassuring that this research did consider more than one health behaviour, these were still not entered into multivariable models simultaneously, thus the combined influence was still not assessed. When considering the duration of breastfeeding rather than initiation, an early study by McLeod et al. (2002) on 490 participants in New Zealand identified no relationship between prenatal alcohol consumption and breastfeeding of any duration. This was supported by Chimoriya et al. (2020). This research utilised data of 1035 mother-infant dyads within the Healthy Smiles Healthy Kids birth cohort, again in Australia. Data were collected at two, four, eight, 12 and 24 months postpartum and no association was identified between alcohol in pregnancy and any breastfeeding duration. It should be noted however, that this research collected data on alcohol consumption postnatally and thus may suffer from recall bias. Moreover, it focused on women from disadvantaged communities. Whilst an important population to study, given the socioeconomic influences on breastfeeding outcomes that were highlighted previously, this may have overshadowed the influence of alcohol consumption. Unfortunately, neither Chimoriya et al. (2020) or McLeod et al. (2002) collected or assessed data on initiation. There is, evidently, a paucity of research within this area and further evidence is required to better understand the influence of prenatal alcohol consumption on breastfeeding outcomes.

1.1.5.1.3.3. Exercise

As with the previous section, there is a lack of evidence that has investigated the influence of prenatal exercise on breastfeeding outcomes. Again, the research appears to focus on exercise during the lactation period. It was only possible to identify two existing studies in this important area, both conducted relatively recently. The first study, conducted by Villar et al. (2018) utilised data collected between 2004-2008 on 2195 mother-infant dyads in Spain. Data on physical activity were collected during pregnancy and breastfeeding data were obtained at six and 14 months postpartum. It was identified that higher levels of physical activity in pregnancy were positively associated with breastfeeding initiation. There was, however, no association with breastfeeding duration. The second study was conducted on a Vietnamese population cohort, with data available for 1715 participants (Nguyen et al., 2019). Participants were recruited mid-pregnancy with a 12 month postpartum follow-up. Participants completed a physical activity questionnaire that reflected exercise in the previous three months. The research identified that participants undertaking higher physical activity levels had reduced likelihood of breastfeeding cessation at 12 months, consequently resulting in higher rates of breastfeeding at this time, compared to participants with the lowest levels of physical activity. Whilst interesting, it should however be noted that this reflects physical activity in early pregnancy rather than the whole of pregnancy. Moreover, Vietnam has very high levels of breastfeeding initiation, at 98%. The low rate of breastfeeding in a variety of populations was previously noted, with this rate considerably higher than most countries, especially Western countries. As such, the identified association may not reflect countries with less successful breastfeeding rates. Overall, the influence of prenatal exercise on breastfeeding outcomes appears to be a recently emerging, but promising, area which would benefit from additional research especially in the UK and Wales.

1.1.5.1.3.4. Dietary patterns

There is a severe lack of existing research on the influence of dietary patterns, or indeed diet, during pregnancy on breastfeeding outcomes. It was only possible to identify one previous study in this area. Rosito et al. (2014) examined the effect of adherence to a pre-defined cariogenic, or high sugar diet in pregnancy, on breastfeeding duration. This study, conducted on 820 participants in Brazil, identified that compared those with a cariogenic diet, those with a non-cariogenic diet had increased likelihood of breastfeeding for six months or more. No data were available for breastfeeding initiation. However, the evidence provided by this study may be considered poor, as the study provided only extremely limited information regarding methodology and analysis strategy. Moreover, unlike the focus of the current thesis, *a priori* dietary patterns were utilised. Consequently, it is highly evident that additional research in this area is crucial before any conclusions can be drawn.

1.1.5.1.3.5. Summary

Breastfeeding is an important behaviour that occurs between mother and child, however the current rates of breastfeeding could be significantly improved especially in the UK. There appears to be a trend in the literature that prenatal smoking is associated with suboptimal breastfeeding outcomes. However, there is a severe paucity of research regarding alcohol consumption, exercise and especially dietary patterns. Consequently, further evidence of the influence of prenatal health behaviours on breastfeeding outcomes is urgently required.

1.1.5.1.4. Mother-infant/child relationship

It has been suggested that the relationship that is formed between a mother, or caregiver, and an infant is the most significant process to occur after birth in the early stages of life (Brockington, 2004). This connection forms the basis for the development of the future relationships that occur throughout childhood and into adulthood (Daglar and Nur, 2018, Waters et al., 2000). Additionally, it can influence a child's social, emotional, language and cognitive development as well as their behaviour and temperament (Sturge-Apple et al., 2006, Kolk et al., 2021, Daglar and Nur, 2018, Le Bas et al., 2020). One aspect of this early relationship is bonding. Maternal-infant bonding begins to develop during pregnancy and continues to develop after birth (Petri et al., 2018, Karakoç and Özkan, 2017, Walsh et al., 2014). It refers to a mothers emotional connectedness to their child (Nolvi et al., 2016) and is comprised of the feelings and emotions experienced by a mother towards her child (Kinsey and Hupcey, 2013, Pallant et al., 2014). Although often utilised interchangeably in research, bonding differs from attachment (Mason, 2015). Bonding is an emotional connection that occurs from the mother to the infant, whereas attachment occurs from the infant to the mother (Kennell and McGrath, 2005). It has been suggested that at a biological level, this bonding occurs to ensure the protection and nurturing and thus survival of the infant (Dubber et al., 2015). This early bonding experience will influence and be predictive of the later relationship between a mother and her child (Daglar and Nur, 2018). Moreover, a mothers responsiveness and behaviour towards her infant will reflect and be a consequence of this bond (Farré-Sender et al., 2018).

Despite it being well established that the environment during pregnancy can influence lifelong outcomes, from biological to psychosocial, the attention of the literature on predictors of the mother-infant relationship appears to be on postnatal factors (Farré-Sender et al., 2018). The risk factors that have been suggested to influence the relationship, but are typically measured postnatally include maternal education level, income, employment status, parity, and age, with maternal depression generally accepted to be a highly influential factor (Figueiredo et al., 2009, Sockol et al., 2014, Tsuchida et al., 2019, Yoshida et al., 2020, Kinsey et al., 2014, McNamara et al., 2019, Cuijlits et al., 2019, Figueiredo et al., 2007, Tichelman et al., 2019, Darvishvand et al., 2018, Rossen et al., 2016, Mazúchová et al., 2020, Kolk et al., 2021, Daglar and Nur, 2018, Farré-Sender et al., 2018). The association between depression and mother-infant bonding has also been identified in the Grown in Wales cohort, which is the focus of this thesis. In this paper by Savory et al. (2020), higher symptoms of prenatal depression were associated with poorer self-reported bonding with their infant at 12 months. However, this noted lack of research on prenatal factors is exemplified further when considering health behaviours.

1.1.5.1.4.1. Health behaviours

To the best of our knowledge, and after a thorough search of the literature, there appears to be no current literature specifically investigating the influence of prenatal maternal health behaviours on the postnatal mother-infant/child relationship. Given that this chapter has provided evidence for and will further demonstrate the influence of these prenatal factors on a range of outcomes, and that the mother child relationship begins to develop during pregnancy, this appears to be an important oversight. Moreover, given the modifiable nature of these potential predictors, unlike other unchangeable sociodemographic factors, establishing the effect of these factors could potentially enable improved relationship outcomes through targeted interventions.

Only two studies were identified with a similar research focus, investigating the earlier maternal-fetal relationship albeit in a contrasting direction to our interest. In research on low income, urban women in America, Alhusen et al. (2012) suggested that the early maternal-fetal attachment (note this differs to bonding) was associated with positive health practices in pregnancy. However, here 'health practices' incorporates the use of harmful substances such as tobacco and alcohol, the balance of rest and exercise, nutrition, but also safety measures, obtaining healthcare and information. As such, ‘health practice’ does not specifically refer to health behaviours in the same way in which this thesis has discussed them. The second study identified was that by Magee et al. (2014), who suggested that lower maternal-fetal attachment (again not bonding) was associated with greater smoking rates in pregnancy in existing smokers. These studies tentatively suggest a link between the early relationship and health behaviours. However, in light of the previous research discussed within this chapter, it is entirely possible that the direction of the relationship differs to that examined here. Indeed, in contrast to these two studies, health behaviours in pregnancy may influence the relationship. Clearly, the evidence base on this area needs to be firmly established before any conclusions can be drawn.

1.1.5.1.4.2. Summary

Despite the importance of the mother-infant/child relationship, and what is known regarding the importance of the pregnancy environment on a variety of outcomes, this is a highly neglected area. The vast majority of the existing literature on risk factors focusses on postnatal predictors, with no research currently available on the influence of prenatal health behaviours on the postnatal relationship. Given that understanding the nature of this relationship could lead to improved outcomes this is a crucial oversight that needs to be addressed.

1.1.5.2. Infant outcomes

1.1.5.2.1. Birthweight

Birthweight is an important indicator of the health status of an infant. Indeed, it is such an important measure that is in included in the national indicators utilised to measure progress on wellbeing goals, outlined in the Wellbeing of Future Generations Act in Wales (Welsh Government, 2015). Traditionally, population-based classifications have been utilised to categorise infants as low, normal or high birthweight (HBW), with LBW defined as below 2.5 kg and HBW as 4 kg or above (Office for National Statistics, 2017). Evidence has suggested that there is a general trend in infants becoming heavier (Ghosh et al., 2018), with global estimates indicating that HBW, or macrosomia, has increased by 15-25% in recent decades (Henriksen, 2008). In Wales, recent statistics have identified that 12.50% of infants were classified as HBW and 6.10% classified as LBW (Welsh Government, 2021). Despite the trend highlighted by Ghosh et al. (2018), the prevalence of LBW infants has gradually increased over the previous 10 year period in Wales (Welsh Government, 2021), with disparities also noted in birthweight prevalence between health boards. Similarly, global data has indicated that 15.50%, or 20 million births, were classified as LBW in 2017 (World Health Organisation, 2017). In light of this high prevalence, birthweight is considered to be a public health concern and consequently there is a global goal to reduce LBW by 30% between 2012 and 2025 (World Health Organisation, 2014).

As highlighted previously, traditionally infants are considered to be LBW if birthweight is below 2.5 kg and HBW if 4 kg or above (Office for National Statistics, 2017). However, many issues have been highlighted with this traditional classification system. For example, the use of arbitrary cut-off points mean there is only marginal difference between an infant born 2.49 kg and 2.5 kg, despite being considered LBW and normal birthweight respectively. Additionally, this system cannot distinguish between those infants born pathologically or physiologically small, and thus some infants may undergo unnecessary investigations and interventions in pregnancy (Gardosi, 2012, Zhang et al., 2010, Gardosi et al., 2009, Gardosi, 2009, Ngo et al., 2015, Dua and Schram, 2006). Consequently, customised birthweight centiles (CBWC) have been developed to overcome these issues. CBWC are calculated by adjusting for factors that research has indicated may affect fetal growth; maternal ethnicity, parity, height and weight as well as gestational age and fetal sex. Utilising CBWC, infants can be classified as small for gestational age (SGA), average for gestational age (AGA) or large for gestational age (LGA). SGA infants are those below the 10^{th} centiles, with SGA considered a proxy measure of fetal growth restriction (FGR), whilst LGA infants are those in the 90^{th} centile or above (Gardosi and Francis, 2009). Using CBWC ensures classifications are based on standardised centiles, thus differing greatly from the traditional unstandardised population-based classifications of LBW and HBW (Ngo et al., 2015). As a result, CBWC provide more accurate classifications of birthweight and have improved the identification of small infants at increased risk of morbidity and mortality (Gardosi et al., 2009, McCowan et al., 2006). CBWC should however be placed in the context of conclusions from the large cross-sectional, multiple country, population-based and multi-ethnic INTERGROWTH study (Villar et al., 2014). This large study established international standards for healthy newborn size for gestational age and determined that all infants, regardless of ethnicity or country of birth, have consistently similar growth potential. This may have implications for the use of CBWC, as it perhaps suggests certain incorporated factors, such as ethnicity, are not necessary. Nevertheless, CBWC remain an important measure that can be easily incorporated within research and clinical settings. Moreover, given the advantages of CBWC, their use has been recommended by the Royal College of Obstetricians and Gynaecologists since 2002 (Royal College of Obstetricians and Gynaecologists, 2013). Unfortunately, however, CBWCs are still rarely utilised in research.

Birth classifications outside of the range considered to be healthy have been associated with a range of suboptimal outcomes. Infants categorised as SGA are at increased risk of neonatal morbidity and mortality, poor neurocognitive skills and development in childhood, as well as increased risk of heart disease and disorders such as diabetes, hypertension and stroke in adulthood (Vik et al., 1996, Flamant and Gascoin, 2013, Morken et al., 2014, Nardozza et al., 2012, Aiken, 2017, Takeuchi et al., 2018, Godfrey, 2001). These birth outcomes also affect the mother, with delivering an SGA infant associated with increased future risk of cardiovascular disease and death (Ngo et al., 2015, Eskild, 2018). Furthermore, LGA infants have a higher likelihood of obesity in childhood (Schellong et al., 2012, Yu et al., 2011). Risk factors that have been associated with birthweight outcomes such as SGA or LGA births include occupation, socioeconomic status, maternal age, parity, BMI, gestational diabetes and hypertension (Weightman et al., 2012, Thomson et al., 2021, McCowan et al., 2010, Khan et al., 2016, Neeharika Ramisetty et al., 2018, Bizuayehu et al., 2021, Hinkle et al., 2014). In terms of biological causes of suboptimal birthweight outcomes this can include the role of placental dysfunction or insufficiency. This nature of this dysfunction can vary, with evidence suggesting causes that include vascular, endocrine and genetics (John, 2017, Henriksen and Clausen, 2008), which can influence the provision of essential nutrients to the fetus. Evidence examining the influence of prenatal health behaviours on birthweight outcomes will now be discussed.

1.1.5.2.1.1. Smoking

There has been considerable interest in the influence of prenatal smoking on birthweight outcomes. It has been possible to identify two studies in Wales that have examined this area. Meis et al. (1997) utilised data of 24,733 births to Caucasian participants from the Cardiff Birth Survey, conducted between 1970-1979. Whilst they examined a range of risk factors, the only health behaviour incorporated was smoking. This early study identified that smoking in pregnancy increased the risk of delivering a LBW infant. This is supported by the second, more recent, study with a focus on a Welsh population, Johnson et al. (2017), which also found that prenatal smoking was a strong risk factor for LBW infants. Unfortunately, neither study accounted for gestational age, nor CBWC in the case of Johnson et al. (2017).

Nevertheless, this association between smoking and suboptimal birthweight outcomes appears to be a trend in the literature. Very occasionally, studies such as that by Míguez and Pereira (2020) conducted in Spain, do not identify an influence of prenatal smoking, however this is not typical of the overall literature. Indeed, a large systematic review and meta-analysis of studies conducted in the Americas concluded that there was a strong association between active smoking in pregnancy and LBW (Pereira et al., 2017). Again, however, CBWC were not considered. Some studies have incorporated the use of partially customised birthweight. For example, Mutsaerts et al. (2014) and Bird et al. (2017) utilised birthweight adjusted for gestational age, whilst Gómez Roig et al. (2017) customised for gestational age and gender and found that smoking in pregnancy was associated with increased risk of SGA infants. The only study identified that utilised near fully customised birthweight was that by McCowan et al. (2010). This research utilised data from the multinational SCOPE cohort, a large multicentre study with participants in Australia, New Zealand, the UK and Ireland. Here, it was again determined that prenatal smoking increased the risk of delivering an SGA infant. Unfortunately, this study focused on nulliparous participants, despite the evidence indicating that parity can influence birthweight, however it is still useful to the current understanding. Overall, it can be suggested that prenatal smoking negatively influences birthweight outcomes, however the use of CBWC is rare and needs to be incorporated within the research.

1.1.5.2.1.2. Alcohol

As with many other areas of research within this thesis, the research environment on the effects of prenatal alcohol consumption on birthweight outcomes has produced mixed results. Some research has found a negative influence of alcohol on birthweight. A large study was conducted by Strandberg-Larsen et al. (2017), involving a pooled meta-analysis of data from nine large European birth cohorts totalling 193,747 participants. Here, it was identified that moderate drinking, defined as six or more drinks per week, was associated with lower birthweight and higher risk of SGA. It was noted, however, that there was heterogeneity between studies in terms of how alcohol consumption was measured. This finding is supported by a somewhat unusual systematic review and meta-analysis by Mamluk et al. (2017). This review focused only on quasi-experimental, negative control comparisons and Mendelian randomisation analyses, in order to reduce the influence of confounding and measurement error. It was concluded that whilst there is some evidence that light alcohol consumption, defined as < 32 g per week, increases the risk of SGA infants, the evidence is lacking.

Research conducted in a range of countries has supported the negative influence of alcohol on birthweight. For example, general alcohol intake, often defined as any alcohol consumption in pregnancy, has been associated with increased risk of LBW and SGA infants in large population based studies in New Zealand (Bird et al., 2017) and South Africa (Zar et al., 2019, Budree et al., 2017) as well as in data from 144,779 records in British Columbia (Popova et al., 2021). Additionally, an early study conducted in the UK utilising ALSPAC data identified that infants born to participants who drank heavily during pregnancy weighed 150 g less than those who abstained (Passaro et al., 1996). Another study conducted with a large sample of 1303 participants in the UK (Nykjaer et al., 2014), determined that consuming two or more units of alcohol per week in trimester one was associated with a 100 g reduction in overall birthweight. Moreover, compared to those who abstain, any alcohol consumption in pregnancy decreased overall CBWC and increased the risk of SGA infants. The evidence from this study is particularly compelling, as unlike all the other research outlined, Nykjaer et al. (2014) actually utilised fully customised birthweight centiles and classifications, outlined by Gardosi et al. (2009), thus overcoming the limitations of the vast majority of this research within this area.

On the other hand, evidence has also found differing results. This includes a systematic review and meta-analysis conducted by Patra et al. (2011), who found that overall whilst heavy alcohol consumption increased the risk of both LBW and SGA infants, light to moderate consumption had no effect. Similarly, O'Keeffe et al. (2015) utilised ALSPAC data of 7597 participants and concluded that whilst light to moderate drinking was not linked to birthweight, heavy drinking reduced birthweight by 0.22 kg compared to abstaining. Unfortunately, the authors did not consider assessing SGA classifications. Moreover, a considerable amount of research has identified no effect of prenatal alcohol consumption on birthweight outcomes. A systematic review and meta-analysis by Pereira et al. (2019) considered studies that assessed different types of alcohol consumption, ranging from light to heavy drinking. The authors concluded that overall, there was no compelling association between alcohol and birthweight outcomes. This supports the conclusions of an earlier systematic review, that also found there was no convincing evidence that low to moderate alcohol consumption influenced birthweight outcomes (Henderson, 2007). This lack of association has been identified in a range of individual studies (Miyake et al., 2014, Pfinder et al., 2013, O'Leary et al., 2009, McCarthy et al., 2013, Chen, 2012). For example, Pfinder et al. (2013) examined two large European cohorts, one based the Netherlands and the other in Germany. When specifically considering alcohol consumption in early pregnancy, there was no association between any level of alcohol consumption and risk of SGA infants. Similarly, McCarthy et al. (2013) utilised the SCOPE cohort, a multinational centre study of 5628 participants to investigate the effects of occasional, low, moderate and heavy alcohol intake in early pregnancy and again found no association between any alcohol intake any either birthweight or SGA risk. Overall, the research in this area suffers from heterogeneity and a frequent failure to examine CBWC outcomes. Additional evidence is required to attempt to elucidate the relationship between prenatal alcohol consumption and birthweight outcomes.

1.1.5.2.1.3. Exercise

There has been a range of research, both intervention and observational in nature, investigating the impact of prenatal exercise on infant birthweight outcomes. Systematic reviews and meta-analyses of exercise RCTs in pregnancy have identified that exercise reduced the risk of macrosomia or LGA infants but reassuringly did not also increase the risk of LBW or SGA births (Davenport et al., 2018b, Wiebe et al., 2015). For example when considering individual studies, Barakat et al. (2016) conducted an RCT in Spain, with 383 and 382 participants in the control and intervention group respectively. This study identified that compared to the exercise group, those that did not exercise in pregnancy were 2.5 times more likely to deliver an infant with macrosomia. As highlighted in many other sections of this chapter, RCT studies to do necessarily reflect the real-life experiences of undertaking exercise in pregnancy, whereas observational studies provide this understanding.

One such study conducted by Pastorino et al. (2019), utilised individual level meta-analysis of data from eight large cohort studies, seven being in Europe and one in the USA, consisting of 74,694 participants. Within this, researchers elucidated a small but consistent association between physical activity in late but not early pregnancy and decreased risk of LGA infants. No association was found for SGA outcomes. Conversely, a small amount of research, including that by McCowan et al. (2010), identified a negative impact of exercise. This study, previously discussed in relation to smoking, utilised data from the SCOPE study, a multicentre study with 3513 participants. Unlike the vast majority of research, this study utilised near fully customised SGA classifications, a significant strength of this evidence. Researchers identified that vigorous exercise in pregnancy, defined as daily exercise leading to heavy breathing or being out of breath, increased the risk of SGA infants. Although this finding is rare, it is crucially important due to the more accurate and recommended use of customisation.

Despite these studies, a large body of research has identified no effect of exercise in pregnancy on birthweight outcomes. A review that focused on RCT studies concluded that exercise interventions in pregnancy do not increase the risk of SGA infants (Vargas-Terrones et al., 2019b). Meanwhile, a systematic review and meta-analysis incorporating both observational and RCT studies also concluded that there was no current evidence of a negative association between exercise and birthweight or risk of SGA or LBW infants (Beetham et al., 2019). However, it was noted yet again that there was large heterogeneity between studies in the measure of and reporting of exercise, making it difficult to compare studies. When considering individual studies, Murtezani et al. (2014) conducted a small RCT with around 30 participants in each group, involving 30 minutes of exercise in sessions conducted from early to late pregnancy. Authors found no influence of the intervention on birthweight outcomes. In further support of this, larger RCT studies such as that by da Silva et al. (2017) conducted with 639 participants in Brazil, also identified no association. However, this study did suffer with low adherence to the sessions and high drop-out rate which may have influenced the findings.

This lack of association was also identified in observational studies. For example, Mutsaerts et al. (2014) utilised data on 2264 participants in a large cohort study in the Netherlands, and found there was no effect of exercise in pregnancy on any birthweight outcomes. Excitingly, a study was identified that investigated this area in Wales (Morgan et al., 2014). This study utilised data from the Growing Up in Wales cohort that measured physical activity using an accelerometer. There was no association determined between high or low levels of objectively measured physical activity and risk of SGA or AGA deliveries. Whilst this research only adjusted for gestational age, it does provide a basis upon which to expand the evidence in Wales. Moreover, given the lack of CBWC utilisation additional research in this area is necessary.

1.1.5.2.1.4. Dietary patterns

To date, there has been a lot of interest in the potential influence of dietary patterns in pregnancy on birthweight outcomes, however as with so many previous sections of this thesis the findings appear to be highly inconsistent. Some studies such as that by Thompson et al. (2010) in New Zealand, have identified that healthy traditional dietary patterns reduce the likelihood of delivering an SGA infant. Alternatively, other studies have identified that healthy Mediterranean dietary pattern adherence or plant based dietary patterns are associated with lower overall birthweight and reduced risk of LGA infants (Timmermans et al., 2012, Zulyniak et al., 2017), with Zulyniak et al. (2017) also identifying an association between a Plant-based dietary pattern and increased risk of SGA. This is similar to Englund-Ögge et al. (2018), who utilised data of 65,904 participants in the Norwegian Mother and Child Cohort Study. Here, it was identified that higher adherence to a Prudent dietary pattern was associated with increased SGA risk, decreased LGA risk and lower overall birthweight, whilst the Traditional dietary pattern was associated with the opposite outcomes. Importantly, it must be noted that this was the only study identified in this area that customised birthweight for maternal weight, height parity, gestational age and infant sex. Other studies have identified that an unhealthy Western dietary pattern is related to increased risk of SGA infants (Knudsen, 2008), whereas further evidence has identified no association (Saunders et al., 2014, Ancira-Moreno et al., 2020). Whilst a strength of many of these studies lies in the large sample sizes, this area suffers as studies rarely utilised CBWC or birthweight adjusted beyond gestational age.

This inconsistency between study findings is highlighted by the numerous reviews of this research area. Some systematic reviews and meta-analyses have determined that whilst there was no clear association between dietary patterns and HBW or LGA infants, healthier dietary patterns or Mediterranean dietary patterns are associated with higher overall birthweight and reduced risk of LBW or SGA (Abdollahi et al., 2021, Gete et al., 2020, Biagi et al., 2019). However, all authors highlight that the associations identified here are weak and not compelling with the quality of studies determined to be low. Alternatively, other reviews determine that whilst individual studies might show trends, overall it is either impossible to draw an overall conclusion or there is no consistent association between dietary patterns in pregnancy and birthweight outcomes (Raghavan et al., 2019, Chia et al., 2019, Kibret et al., 2019). It is possible that this inconsistency and difficulty in drawing conclusions is again due to the highly heterogenous nature of the literature in this area. Indeed, there are considerable differences in research methodology, such as in the choice of dietary pattern measures and timing of assessments. Moreover, it was emphasised by Raghavan et al. (2019) that the ability to form conclusions was hampered by the lack of adjustment of birthweight for even the basic factors of gestational age and sex. Evidently, stronger research utilising CBWC is necessary to better understand if there is an effect of prenatal dietary patterns on birthweight outcomes.

1.1.5.2.1.5. Summary

Birthweight is typically measured utilising traditional classifications, despite the advantages associated with utilising CBWC. Research appears to indicate that prenatal smoking negatively influences birthweight. On the other hand, the evidence for the effect of alcohol consumption, exercise and dietary patterns in pregnancy is highly contradictory. Moreover, the existing evidence rarely utilises CBWC classifications. Further research utilising the more accurate CBWC is necessary to fully understand the influence of prenatal health behaviours on birthweight outcomes.

1.1.5.2.2. APGAR scores

The APGAR scoring system is a universally recognised and utilised measure to rapidly assess the health status of a newborn (Razaz et al., 2019). It was developed to assess the heart rate, respiration, colour, muscle tone and reflex irritability (Apgar, 1952). It is typically measured at one and five minutes after birth. The one minute measure reflects how well the infant tolerated the birthing process and the five minute measure indicates how well the infant is coping outside of the womb (Cnattingius et al., 2020), with the five minute measure believed to be the better indicator of infant survival (Drage et al., 1964). Some countries and situations also require APGAR to be measured at 10 minutes after birth, however, this is far less common. Factors that have been suggested to influence APGAR scores include maternal education level, type of employment, socioeconomic status, BMI, parity, maternal age, prenatal depression, mode of delivery, gestational age and birthweight (Odd et al., 2008, Odintsova et al., 2019, Lai et al., 2017, Thorngren-Jerneck and Herbst, 2001, Foo et al., 2016, Straube et al., 2010, Zhu et al., 2015, Papachatzi et al., 2013, Marcus, 2009, Kalliala et al., 2017, Wong et al., 2020, Zhao et al., 2020). The influence of modifiable prenatal health behaviours is less frequently examined.

APGAR scores are measured from zero to 10, with a score of seven or above typically indicative of good health (Apgar, 1952). Low APGAR scores have been associated with outcomes that include increased risk of neonatal morbidity and mortality, cancers in infancy, and longer term outcomes such as epilepsy and cerebral palsy, motor control, cognitive, emotional and language development, autism and educational outcomes (Razaz et al., 2019, Persson et al., 2018, Razaz et al., 2016, Li et al., 2012, Chaimay et al., 2006, Stuart et al., 2011, Krebs et al., 2001, Weinberger et al., 2000, Yisma et al., 2021, Modabbernia et al., 2019). Reassuringly, the most recently available data demonstrated that in Wales in 2020, 98% of infants achieved an APGAR score of seven or above at five minutes (Welsh

Government, 2021). Furthermore, studies have recently indicated that scores in the low ‘normal’ range, that is scores of seven to nine, may also be associated with poorer outcomes compared to those with scores of 10 (Razaz et al., 2019, Cnattingius et al., 2020, Persson et al., 2018). Statistics utilising the low ‘normal’ category are not typically provided.

1.1.5.2.2.1. Smoking

There is surprisingly little evidence regarding the influence of smoking during pregnancy on APGAR scores, and with a few exceptions the research is typically older. Some studies have provided evidence that smoking affects APGAR scores. For example, two large data registry studies from Sweden and Germany, with over 1 million participants and 170,254 participants respectively, identified that smoking increased the risk of APGAR scores below seven at five and 10 minutes (Thorngren-Jerneck and Herbst, 2001, Hammoud et al., 2005). Similarly, in a recent but considerably smaller study of 301 participants in Zanzibar, smoking was associated with the increased likelihood of low one minute APGAR scores (Abdallah et al., 2021). However, adjustment for confounders is an issue within these studies. Whilst Hammoud et al. (2005) stated adjustment took place, it is unclear what confounding factors were included. Moreover, it appears that no adjustment took place in the studies by Thorngren-Jerneck and Herbst (2001) and Abdallah et al. (2021). Given that a variety of biological and sociodemographic variables have been indicated to influence APGAR scores, this absence of adjustment may lead to inaccurate conclusions.

This issue is supported by a review by Odintsova et al. (2019) which concluded that overall, the majority of studies found no association between smoking in pregnancy and APGAR scores after controlling for potentially confounding variables. Indeed, in two studies conducted in America utilising data on different periods from the National Collaborative Perinatal Project, there was no difference in APGAR scores between smoking and non-smoking groups, or an association between smoking and APGAR scores following adjustment for confounders (Stroud et al., 2009, Gilman et al., 2008). Larger studies have also been undertaken which had similar findings. Lai et al. (2017) conducted a study of 58,429 participants in Australia investigating perinatal risk factors for APGAR scores. Although the definition of perinatal smoking is unclear, authors found no association between smoking and low, moderate or high APGAR scores at five minutes. Furthermore, Straube et al. (2010) identified no association between prenatal smoking and five minute APGAR scores in a large study of 465,964 participants in Germany. Consequently, overall it appears that there is no relationship between smoking in pregnancy and APGAR score outcomes.

However, no studies were identified that investigated this area in the UK, and given the older nature of the evidence, further well-adjusted studies would be beneficial in this area.

1.1.5.2.2.2. Alcohol

There is also limited existing research available on the influence of prenatal alcohol consumption on APGAR outcomes. When considering the few studies that were identified, overall there appears to be no evidence of an effect of alcohol. In early research conducted in Bristol with 500 participants, James et al. (1995) identified no effect of low-to-moderate alcohol consumption on one and five minute APGAR scores. This finding is supported by another early study of similar sample size, in this case 605 participants, in Australia which again identified no association (Walpole et al., 1990). Equally, more recent research reached similar conclusions. These larger studies, conducted in Australia via the use of birth records for 22,193 participants (Zhao et al., 2017) and in two sites in America with 4496 participants (Lundsberg et al., 2015), again found no relationship between any alcohol consumption and low to moderate alcohol intake on the risk of low one and five minute APGAR scores. Only one study was identified that found an association between alcohol consumption and increased likelihood of low one minute APGAR scores (Abdallah et al., 2021). However, this study was discussed previously in relation to smoking where it was highlighted that no adjustment for confounding variables took place. As such, the evidence from this particular study is limited. Whilst there appears to be no overall effect of alcohol consumption, we were only able to identify these five studies in this area. Moreover, even the more recent studies discussed incorporated older data, from 1996-2000 and 2009-2011 (Lundsberg et al., 2015, Zhao et al., 2017). Thus, the evidence base could be expanded and updated with more recent data.

1.1.5.2.2.3. Exercise

There appears to have been more research interest on the influence of prenatal exercise on APGAR scores. As with the many other outcomes that have been discussed within this thesis, the majority of the existing research focuses heavily on exercise RCTs. Two recent systematic reviews and meta analyses of intervention studies concluded that overall the meta-analyses indicated no significant overall association between physical activity in pregnancy and APGAR scores (Veisy et al., 2021, Davenport et al., 2018b). However, Veisy et al. (2021) did highlight that individual studies have occasionally shown an effect. For example, two RCT studies, albeit with relatively low participant numbers of 63 in Kosovo (Murtezani et al., 2014) and 105 in Norway (Haakstad and Bø, 2011) respectively, involved an exercise programme throughout pregnancy. Both studies identified high one and five minute APGAR scores in the women involved in the exercise group. However, other RCT studies, such as that conducted by Barakat et al. (2014) with 200 participants in Spain found no difference between exercise and control groups on one and five minute APGAR scores.

As highlighted previously, whilst RCTs are important to our knowledge base, they do not necessarily reflect the exercise typically undertaken by women in pregnancy. Observational and cohort studies are important to fully understand the influence of typical exercise behaviour in pregnancy. This has been partly addressed in a review by Michalek et al. (2020) which incorporated multiple study types. The authors concluded that exercise in pregnancy appeared to have either a neutral or, very occasionally, a positive effect but no detrimental effects on APGAR scores were apparent. As with many studies in this thesis, the authors did note that there was a high level of heterogeneity between studies. Examples of such studies include that by Wojtyla et al. (2012), which investigated data on 2852 participants in Poland in which exercise was self-reported on a questionnaire. This research found no effect of exercise on APGAR outcomes. Similarly, and highly relevant for the current body of work, research by Morgan et al. (2014) was conducted on this area in Wales. Here, 466 participants were involved in a study utilising an accelerometer to measure physical activity. It was determined that there was no association between low or high levels of physical activity and low APGAR scores at five minutes. Overall, it appears that exercise in pregnancy has no detrimental effects on APGAR scores. However, as only one study was identified in Wales, additional research on Welsh populations would enhance the current knowledge base in this area.

1.1.5.2.2.4. Dietary patterns

Whilst there has been a lot of interest in the relationship between prenatal dietary patterns and birth outcomes such as birthweight, there has been minimal research on APGAR scores. Indeed, even reviews aiming to investigate the influence of dietary patterns on birth outcomes, such as that by Raghavan et al. (2019), neglect to incorporate or even acknowledge APGAR scores. It was only possible to identify one study that investigated this area. This study by Mikeš et al. (2021) utilised older data of 4320 participants collected between 1991-1992 within the Czech component of the European Longitudinal Study of Pregnancy and Childhood (ELSPAC). Authors concluded that there was no association between either the unhealthy or healthy/traditional dietary patterns identified and APGAR scores at five minutes. Given that there is only one study in this area it is impossible to currently draw conclusions on the influence of dietary patterns on APGAR scores. Research in this area utilising more contemporary data and cohorts is urgently required.

1.1.5.2.2.5. Summary

APGAR scores are an important, universally utilised measure of a newborn infants health status. Whilst research has considered sociodemographic and biological risk factors, with the exception of prenatal exercise there has been extremely little attention given to the influence of health behaviours in pregnancy. This area needs to be investigated further before conclusions can be drawn.

1.1.5.2.3. Neurodevelopment

It has been argued that neurodevelopment is one of the most crucial processes that occurs during the first 1000 days (Niño Cruz et al., 2018). Neurodevelopment begins early in pregnancy and continues into adolescence (O'Donnell et al., 2014). However, the period of greatest vulnerability of the brain begins in the antenatal period especially around the third trimester, where it begins to undergo the rapid growth that continues until two years of age, where it reaches 80% of the adult weight (O'donnell et al., 2009, McCann and Ames, 2005). During this time the brain is especially vulnerable to environmental factors (Bjarnadóttir et al., 2019). Indeed, evidence has identified that many neurodevelopmental disorders originate during early brain development (Koutra et al., 2012). Thus, suboptimal conditions during pregnancy, which may include health behaviours, have the potential for great impact on an infant's neurodevelopment. Neurodevelopment includes the development of neurological pathways influencing areas such as cognition and language (Bjarnadóttir et al., 2019, Thompson and Nelson, 2001, Hanson and Gluckman, 2014), which will be the focus of this thesis.

A variety of factors have been found to influence neurodevelopmental outcomes, with socioeconomic status and parity frequently identified (González et al., 2020, Bjarnadóttir et al., 2019, Stein et al., 2014, Donald et al., 2019, Putnick et al., 2007, Koutra et al., 2012). Other factors that have been identified include maternal education, pre-pregnancy BMI, mental health, maternal age, fetal sex, gestational age and breastfeeding (Leventakou et al., 2015, Casas et al., 2013, González et al., 2020, Bjarnadóttir et al., 2019, Valla et al., 2017, Stein et al., 2014, Smith-Nielsen et al., 2016, Donald et al., 2019, Koutra et al., 2013, Koutra et al., 2012). The influence of prenatal health behaviours on cognitive and language developmental outcomes will now be discussed.

1.1.5.2.3.1. Smoking

Whilst in general there has been interest in the influence of smoking on neurodevelopmental outcomes, this research tends to focus on a wide range of ages. Unfortunately, there is less information available around the age of 12 months, the age of interest within this thesis, a recurring issue for all health behaviours in this area. Of the research that does exist, the evidence regarding the effect of prenatal smoking on cognition and language development appears mixed. Some research has highlighted an association between smoking and poorer neurodevelopmental outcomes. Hernández-Martínez et al. (2017) conducted a longitudinal study in Spain, with data available for 156 and 134 mother-infant dyads when the infants were six and 12 months of age respectively. The Bayley Scales of Infant Development (BSID) were utilised to measure cognition and the Macarthur-Bates Communicative Development Inventories (MBCDI) to measure language. Whilst there was no association at six months, at 12 months prenatal smoking was associated with poorer cognition and language scores. Similarly, Polańska et al. (2015) identified the same association in 12 month old infants when utilising data from 538 participants of the Polish Mother and Child Cohort. In contrast to the previous research, Bjarnadóttir et al. (2019) measured language at 12 months utilising the MBCDI in 650 infants in Copenhagen and identified the opposite association. Indeed, the researchers found that prenatal smoking was associated with increased language scores.

Conversely other research has identified no associations between prenatal smoking and neurodevelopmental outcomes. This includes studies such as that by Donald et al. (2019), Negrão et al. (2020) and Koutra et al. (2013), all of whom identified no effect of smoking on either cognitive of language development measured utilising the BSID. However, it should be highlighted that whereas the previous research was focused on infants aged 12 months, this research incorporated older infants. Furthermore, Koutra et al. (2012) and Donald et al. (2019) utilised data in 599 infants in the Rhea cohort in Greece and 732 infants in the South African Drakenstein Child Health Study respectively. Again, neither study identified any association between cognitive or language skills at 18 months or two years of age. Similarly, in a large Brazilian study of 1006 infants, Negrão et al. (2020) concluded there was no association between prenatal smoking and cognitive development. Clearly, there is a discrepancy regarding the influence of prenatal smoking on infant neurodevelopment. This again could be partly due to the heterogeneity between studies regarding measures utilised and infant ages. Moreover, no research was identified in the UK. As such, further research on the current age of interest will enhance the evidence base in this area.

1.1.5.2.3.2. Alcohol

As with many outcomes investigated within this thesis, the evidence for the effect of low to moderate prenatal alcohol consumption on infant neurodevelopmental outcomes varies. Some studies have found a perhaps surprising effect of alcohol. A review by Flak et al. (2014) concluded there was a small but positive association between mild to moderate prenatal alcohol consumption and cognition, although this review incorporated a range of ages, not only infants, which may have influenced conclusions. Nevertheless, this is supported by findings from a large cohort study in Australia (McCormack et al., 2018). McCormack et al. (2018) utilised data on alcohol intake in each trimester of 1623 participants in the Triple B Study cohort. The authors identified that low level alcohol consumption in trimester two was associated with higher cognitive ability as measured on the BSID at 12 months of age, compared to infants born to abstainers. As such, these studies appear to indicate a positive effect of alcohol consumption.

Despite these few studies, the literature overwhelmingly appears to demonstrate that there is no association between only low to moderate prenatal alcohol consumption and infant cognitive and language skills. All studies that will be discussed here utilised the BSID to measure neurodevelopment. Williams Brown et al. (2010) analysed data from the Early Childhood Longitudinal Studies birth cohort in America to identify that cognitive scores were related to a dose response. Here, scores decreased as the amount of alcohol consumed increased. However, although not clear in the paper, there was no significant association between these variables, only a generally direction of relationship and the participant number was not declared. Moreover, whilst the aim was to collect data at nine months, the ultimate age range was large at six to 22 months. Thus, these factors make it difficult to draw conclusions from this study. Nevertheless, another albeit small study in America found similar results. Bakhireva et al. (2018) investigated the effect of prenatal alcohol consumption on 93 infants aged between five and eight months of age. 39 of these infants were considered prenatally exposed to alcohol. Here, there was no association found between low to moderate alcohol consumption and cognitive and language abilities.

This is further supported by studies from a range of countries such as Australia, South America, Brazil and Spain who investigated this area in infants aged 12 months to two years, with sample sizes ranging from 732 to 1570 participants (Halliday et al., 2017, Donald et al., 2019, Polańska et al., 2015). All studies concluded that there was no association between prenatal alcohol consumption and the neurodevelopmental outcomes of cognition or language. To our current knowledge, no studies on this age group or domains of neurodevelopment have been conducted in the UK, instead they tend to examine later ages and domains such as IQ and academic performance and typically all use data from the same cohort, ALSPAC (Alati et al., 2013, Zuccolo et al., 2013, Murray et al., 2016, von Hinke Kessler Scholder et al., 2014). Accordingly, despite this apparent trend of no effect of prenatal alcohol consumption on neurodevelopmental outcomes, this needs to be investigated further in a UK population.

1.1.5.2.3.3. Exercise

Similarly, there has been only minimal research with mixed findings on the influence of prenatal exercise on infant neurodevelopmental outcomes. Two reviews were identified that investigated the literature in this area. Niño Cruz et al. (2018) conducted a systematic review and Álvarez-Bueno et al. (2018) a narrative review and both reached a similar conclusion that despite inconsistencies in the individual studies, overall physical activity was positively associated with language development in the first 18 months. However, there was no overall association with cognitive outcomes. It was emphasised, however, that the high level of heterogeneity between studies, a recurring issue in this general area, made comparisons difficult (Niño Cruz et al., 2018). For example, within the small number of studies identified, the research had greatly varying sample sizes, measures of neurodevelopment and even timepoints of data collection for both exercise and neurodevelopment. Nevertheless, another review, this time a systematic review and meta-analysis of RCT studies, again identified no association between prenatal exercise and cognitive outcomes (Davenport et al., 2018b).

An example of a study that was included in the reviews is Jukic et al. (2013). To the best of our knowledge, this is the only study that has investigated this specific area in a UK population. Jukic et al. (2013) analysed data from 7162 participants within the ALSPAC cohort to assess the influence of physical activity at 18 weeks on neurodevelopment at 15 months. This research identified that higher levels of physical activity were associated with higher levels of language development. Unfortunately, the study did not assess cognitive development and given that initial ALSPAC data collection occurred in the 1990s, further research with more recent data would be beneficial. There has only been one study conducted in this area since the publication of the reviews. Nakahara et al. (2021) undertook a large study in Japan of 103,062 participants, utilising the Ages and Stages Questionnaire to assess language at 12 months of age. The authors identified that there was no association between prenatal exercise and language development at 12 months, and consequently differs to the conclusions of the previous reviews. As such, given the limitations of the existing research, this area needs to be further explored to improve the understanding.

1.1.5.2.3.4. Dietary patterns

Research into the effect of prenatal diet on infant neurodevelopmental outcomes largely focuses on the influence of diet quality or individual food components. For example, there is a large body of literature that has implicated free fatty acids, such as omega three and omega six, with neurocognitive function and development, albeit with mixed conclusions (Basak et al., 2020, Makrides et al., 2010, Heath et al., 2022). There has been very little literature investigating the influence of dietary patterns in this area, despite the advantages associated with this measure that were discussed previously. This issue was highlighted by a systematic review that originally aimed to investigate the influence of only dietary patterns on neurodevelopmental outcomes, but was forced to expand the focus to include diet quality due to the paucity of existing research (Borge, 2017). Of the four dietary pattern studies that were identified by this review, none focused on our age or domains of interest, instead investigating temperament, intelligence and emotional development (Jacka et al., 2013, Steenweg-de Graaff, 2014, Barker et al., 2013, Pina-Camacho et al., 2015). Although the authors did not focus on dietary patterns and also included a range of child ages, Borge (2017) concluded that better prenatal dietary quality was associated with improved cognition outcomes. Whilst this might indicate that healthier dietary patterns could be related to better neurodevelopmental outcomes, without research into this specific area it is not possible to form any conclusions. Consequently, additional research investigating the influence of prenatal dietary patterns on infant cognitive and language development which greatly enhance the current evidence base.

1.1.5.2.3.5. Summary

The process of neurodevelopment is initiated during pregnancy and as such may be highly susceptible to health behaviours undertaken during this time. Much of the existing research in this area suffers from heterogeneity in terms of the measures utilised and the timepoints of data collection. As such, not only is there limited research available in this area but the existing findings have mixed conclusions. Consequently, it is necessary to undertake further assessment of the influence of prenatal dietary patterns on infant neurodevelopmental outcomes.

1.1.5.2.4. Temperament .

Temperament refers to the behavioural tendencies related to emotional responses and reactions to stimuli after birth (Takegata et al., 2021, Goldsmith et al., 1987). It is argued to have a biological basis, existing and developing from early infancy prior to higher cognition (Goldsmith et al., 1987). Whilst there are variations in how temperament has been conceptualised, a popular and frequently utilised definition is that temperament refers to constitutionally based individual difference self-regulation, motor and emotional reactivity, which remain relatively stable over time (Gartstein and Skinner, 2018, Rothbart and Bates, 1981). Three major dimensions have been suggested to represent temperament: negative affectivity, surgency or extraversion and effortful control, which is also referred to as regulatory capacity (Rothbart, 1981). Negative affectivity is related to displays of mood instability, distress, fearfulness and overall negative reactivity (Rothbart, 1981). Surgency refers to displays of pleasure and approach behaviours, such as smiling or laughing and high activity levels (Gartstein and Skinner, 2018). Finally, effortful control reflects an infants ability to maintain task attention, resist distractions and to refrain from a desired behaviour (Rothbart and Bates, 1981).

Temperament is considered the basis upon which future personality and behaviour develops and consequently early temperament can have significant implications for longer term child outcomes. Evidence has suggested that early temperament is associated with outcomes that include cognitive development, educational attainment, emotional and behavioural problems, physical health, obesity and mental health conditions such as psychopathology (Schoeps et al., 2022, Abulizi et al., 2017, Peterson et al., 2018, Gartstein et al., 2016, Goodnight et al., 2016, Sayal et al., 2014, Anzman-Frasca et al., 2012, Morales et al., 2021, Eisenberg et al., 2009, De Pauw et al., 2009). Factors that have been implicated in the development of infant temperament include socioeconomic status, income, maternal mental health, pre-term birth and parity (Tester-Jones et al., 2015, Takegata et al., 2021, Korja et al., 2017, Erickson et al., 2017, Provenzi et al., 2021, Davis et al., 2007, Bornstein et al., 2015, Jansen et al., 2009, Conejero and Rueda, 2018, Takács et al., 2021). The evidence regarding the influence of prenatal health behaviours will now be explored.

1.1.5.2.4.1. Smoking

There has been research interest into the influence of prenatal smoking on early temperament outcomes. Some studies, such as that by Martin et al. (2006) utilised data on 6388 infants from the Helsinki Longitudinal Project, the large sample size being a considerable strength of the research. The researchers investigated temperament at six months and five years of age utilising the Carey Infant Temperament Questionnaire and Parent Temperament Questionnaire respectively. It was identified that prenatal smoking was associated with reduced negative affectivity at both ages. Other research has identified a negative influence of prenatal smoking on temperament outcomes. For example, although younger than the current age of interest, in a study of 98 four week old infants in America prenatal smoking was associated with increased negative temperament (Wiebe et al., 2009). Similarly, in research involving Infant Behaviour Questionnaire (IBQ) data of 115 seven month old infants (Schuetze and Eiden, 2007), prenatal smoking was related to increased likelihood of infant negative effect. A dose response was also noted, highlighting that negative affect increased as the level of smoking increased. Unfortunately, no other domains were assessed and the country in which this study was conducted is unclear. This is also supported by research undertaken in the UK with 71 six month old infants, which also found that prenatal smoking increased negative temperament, although no adjustment for confounders took place (Mundy, 2009). This trend in the literature was confirmed by a large systematic review and meta-analysis by Froggatt et al. (2020). Ultimately it was determined that despite heterogeneity between studies there was compelling evidence indicating that prenatal smoking was associated with suboptimal temperament outcomes. This includes decreased regulatory capacity and increased negativity and overall difficult temperament across a range of ages. No effect was found for surgency. It was not possible to identify any studies investigating the influence of prenatal smoking in early childhood, particularly around the age of four years. As such, the influence of prenatal smoking on longer term outcomes requires more evidence.

1.1.5.2.4.2. Alcohol

There is not a vast literature base for the influence of low to moderate prenatal alcohol consumption on early temperament outcomes. Occasionally, research such as that by Williams Brown et al. (2010) identifies no influence on positive or negative affectivity in nine month old infants, as measured by the behaviour component of the BSID. Overall, the literature appears to indicate a negative influence of prenatal alcohol consumption. In a study of 93 12 month old infants in America utilising the IBQ, Bakhireva et al. (2018) determined that prenatal alcohol consumption increased negative affect. However, no effect was identified for either surgency or effortful control. Similarly, Schoeps et al. (2018) utilised data of 6156 participants within the Growing Up in New Zealand cohort. It was found that even low levels of alcohol consumption increased negative affectivity in nine month old infants, but had no influence on other domains of temperament. This finding was supported by a later study within the same cohort (Schoeps et al., 2022). Unusually for this area of research, the combined influence of multiple health behaviours was considered. It was again identified that participants who drank less alcohol in pregnancy were more likely to have an infant with less difficult temperament. Given the limited available research, this area requires further investigation.

1.1.5.2.4.3. Exercise

Despite the evidence discussed throughout this thesis on the influence of prenatal exercise on both maternal and infant outcomes, very little research has examined the effect of prenatal exercise on early temperament. Indeed, only one previous study was identified that investigated a similar area. Schoeps et al. (2022) considered the influence of pre-pregnancy exercise on temperament outcomes of nine month old infants in the Growing Up in New Zealand cohort. This study has been discussed in relation to the other prenatal health behaviours of interest. Here, the authors identified that participants who undertook higher levels of pre-pregnancy exercise were more likely to have infants with a less difficult temperament, as measured at nine months of age. Whilst this study does not focus on prenatal exercise behaviour, it does provide evidence to support investigating this area. Thus, this neglected topic would benefit from additional research in order to understand the influence of prenatal exercise on infant and child temperament.

1.1.5.2.4.4. Dietary patterns

There has been very little previous interest in the potential influence of prenatal dietary patterns of temperament outcomes in either infancy or childhood. Instead, existing literature tends to consider only the effect of dietary components rather than overall diet, an oversight as previously discussed in this chapter. For example, Gustafsson et al. (2016) considered the effect of dietary fat intake and Hahn-Holbrook et al. (2019) investigated Omega-3 fatty acids. Only one previous study was identified within this area, which was published very recently. Schoeps et al. (2022) was previously discussed in relation to alcohol and exercise. This research utilised data of 3968 participants within the Growing Up in New

Zealand cohort, which measured infant temperament at nine months of age utilising the IBQ. A major strength of this study lies in the consideration of multiple health behaviours and the use of extensive and thorough pathway analysis. Here, it was identified that the healthier dietary patterns categorised as Healthy and Fusion, were associated with improved infant temperament, specifically it reduced negativity. Evidently this is an emerging and previously neglected area that would benefit from additional research.

1.1.5.2.4.5. Summary

Early temperament forms the basis upon which later personality and behaviour develops. There has not been a wealth of data investigating the influence of prenatal health behaviours on temperament outcomes. Although prenatal smoking and alcohol consumption appears to have a negative influence in the area, there is a lack of research regarding exercise and dietary patterns. Moreover, research does not tend to consider temperament in early childhood or UK populations. As such, the evidence base within this area needs to be greatly expanded in order to fully understand the influence of prenatal health behaviours.

1.2. Summary

Pregnancy is a crucial time in a woman’s life, however overall pregnancy is an area that is often neglected in research. As discussed, the pregnancy environment has the potential to influence the health of both mother and child. Maternal health behaviours are one such potentially modifiable environmental influence. This chapter aimed to present evidence regarding the nature and importance of prenatal health behaviours, and an overview of current state of the literature regarding the influence of prenatal health behaviours on a range of maternal and infant outcomes. A consistent message can be identified throughout which is that the current evidence base is often highly varied in the methodology and overall findings. Moreover, the influence of prenatal health behaviours on some important outcomes, such as the mother-child relationship has hardly been explored. Studies also typically focus on individual health behaviours despite them rarely occurring in isolation, which could be influencing findings. Finally, there is an extreme lack of research into this area in Wales, despite the differences between Wales and other UK nations, which ensures that assumptions should not be made regarding generalisability.

It is hoped that addressing these gaps in the existing literature will provide improved understanding of maternal health behaviours undertaken by women in Wales. This improved understanding could form the essential basis of and targets for future interventions and focused support to improve pregnancy outcomes for women and infants in Wales. Moreover, as each of the outcomes explored within this chapter are also associated with further outcomes, this also has the potential to improve future health and development.

1.3. Research questions, hypotheses and aims

This thesis seeks to tackle this gap in the existing literature and provide answers to two main research questions 1) What are the health behaviours undertaken in pregnancy by women in Wales? 2) What is the influence of the maternal health behaviours in pregnancy on maternal and infant outcomes in Wales?

Through these research questions the following hypotheses will be explored 1) Healthy maternal health behaviours in pregnancy are associated with positive maternal and infant outcomes 2) Unhealthy maternal health behaviours in pregnancy are associated with negative or suboptimal maternal and infant outcomes.

The research questions and hypotheses will be explored and addressed through the following aims and objectives.

1) To understand the nature of the maternal health behaviours undertaken in pregnancy within the Grown in Wales cohort.
    - To assess the frequency of smoking, alcohol consumption and exercise in pregnancy.
    - To establish the factors associated with each of the identified health behaviours.
    - To determine the dietary patterns present during pregnancy.
    - To consider the factors related to the derived maternal dietary patterns.
    - To establish the suitability of and validate the dietary patterns by testing against an outcome i.e. infant birthweight.
2) To determine the influence of maternal health behaviours in pregnancy on short and longer term maternal outcomes.
    - To establish the association between maternal prenatal health behaviours and GWG.
    - To determine the association between maternal prenatal health behaviours and perinatal maternal mental health, in the form of depression & anxiety symptoms.

- To investigate the association between maternal prenatal health behaviours and maternal care in the form of breast feeding & the mother-infant/child relationship.

3) To assess the influence of maternal health behaviours in pregnancy on short and longer term infant health and development.

    - To investigate the association between maternal prenatal health behaviours and immediate birth outcomes in the form of birthweight, CBWC and APGAR scores.
    - To assess the association between maternal prenatal health behaviours and infant neurodevelopment in the form of cognition and language ability.
    - To consider the association between maternal prenatal health behaviours and infant and child temperament.

Chapter 2 - Methods

2.1. Methods

This thesis utilises data from the longitudinal Grown in Wales (GiW) cohort, initiated in 2015 to investigate the relationship between perinatal maternal mental health and placental function. The cohort contains a wealth of information that has allowed additional research to be undertaken. This includes biological samples, demographic, health behaviour and mental health data as well as measures of infant development. The specific data and measures utilised within the thesis are outlined in this chapter.

2.1.1. Recruitment

Recruitment to the cohort took place between 1st September 2015 and 31st November 2016 at the University Hospital of Wales (UHW) located in Cardiff, South East Wales. Participants were approached at the morning presurgical appointment for a booked elective caesarean section (ELCS) delivery by one of two trained research midwives. ELCS deliveries were selected to maximise the collection of biological samples, such as placenta. Women were invited to participate in the cohort if they were between the ages of 18-45, could speak fluent English and if records indicated it was a singleton pregnancy at term with no known fetal anomalies, infections or diseases. Participants provided written consent at recruitment to be contacted for follow-up postnatal data collection until the child was aged 12. Full ethical approval was obtained via the Wales Research Ethics Committee (REC), reference 15/WA/0004.

To date, participants have been involved in five waves of data collection; one prenatal and four postnatal timepoints. Data collection waves have taken place at recruitment (A1), within seven days of birth (P1), 10 weeks after birth (P2), when the infant reached 12 months of age (Y1) and most recently at four years of age (Y4). This thesis utilises data from the timepoints A1, Y1 and Y4. An outline of overall participant numbers and retention rates are displayed in Figure 2.1.

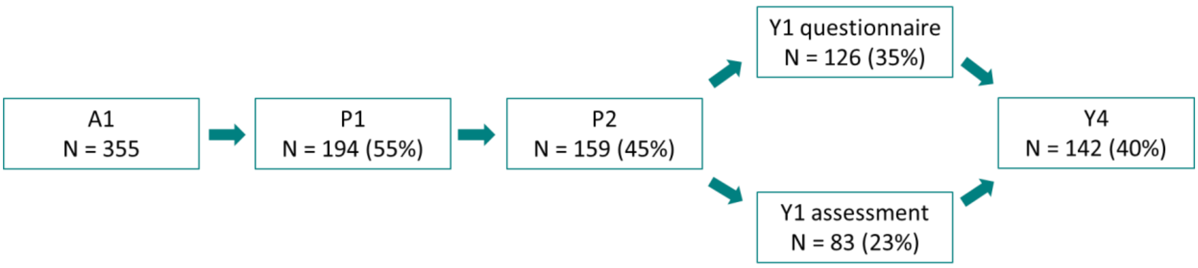


Figure 2.1 An outline of participant numbers and retention rates at each data collection timepoint

2.1.2. Measures

The GiW cohort contains a range of data, as displayed in Figure 2.2. Data from midwife recorded notes and all questionnaires for each participant at each timepoint within the cohort were checked at the start of the PhD to ensure the accuracy of data entry. This section will outline the specific data at each timepoint that was utilised within the thesis.

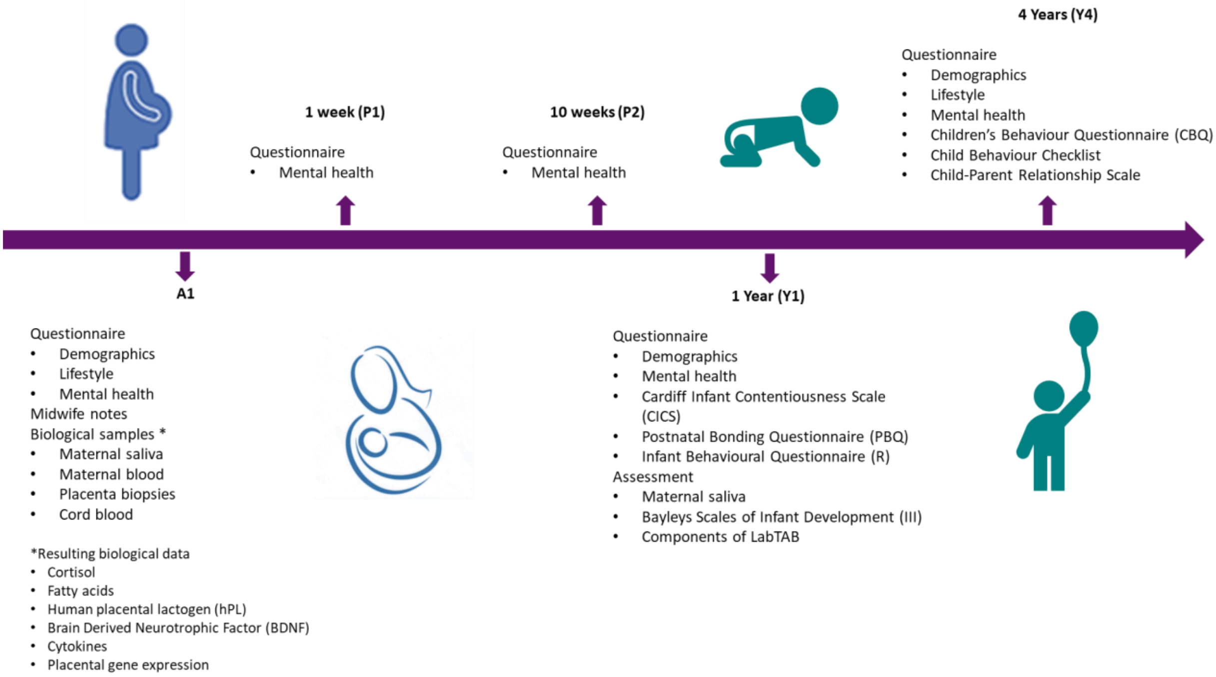


Figure 2.2 An overview of data collection at each timepoint within the cohort

2.1.3. A1 timepoint

2.1.3.1. Questionnaire

2.1.3.1.1. Demographics

The general demographic data collected within the A1 questionnaire included data on pre-pregnancy weight (continuous) and height (continuous), both of which were utilised to calculated pre-pregnancy body mass index (BMI) (continuous & categorical: Underweight/ Healthy/Overweight/Obese). It also incorporated data on maternal ethnicity (categorical: Caucasian/Non-Caucasian), highest education level (categorical: Left before GCSE/GCSE or vocational/A-levels/University/Postgraduate) and family income before deductions (categorical: <£18,000/£18-25,000/£25-43,000/Do not wish to say). These specific education and income variables were utilised within Chapter Three when examining factors associated with the occurrence of the health behaviours in pregnancy. In Chapters Four and Five, education and income were only utilised as potentially confounding variables in selected adjusted analyses. For the purposes of these chapters, and in line with previous similar research in this area, these variables were recategorized into dichotomous variables. Specifically, education was recategorized as ‘University or above’ or ‘Below University’, whilst income was recategorized as ‘£25,000 or above’ or ‘below £25,000’. As with previous research, this was undertaken to reduce the number of levels within these variables utilised as confounders, in order to prevent over-fitting these adjusted models.

Additionally, the questionnaire recorded participants postcodes. The anonymised postcodes enabled the calculation of Welsh Index of Multiple Deprivation (WIMD) scores (continuous) (https://statswales.gov.wales/Catalogue/Community-Safety-and-Social-Inclusion/Welsh-Index-of-Multiple-Deprivation). The WIMD is the Welsh Governments official measure of relative deprivation for 1909 small areas in Wales with each area given a score. The overall WIMD score consists of several different measures of deprivation: income, employment, health, education, access to services, community services, physical environment and housing. WIMD has a possible range of 1 to 1909 with a high score reflecting an area of lower deprivation and, conversely, a low score reflecting an area of higher deprivation.

2.1.3.1.2. Health behaviours

The health behaviour component of the A1 questionnaire collected data on alcohol, smoking, exercise and diet. Participants were asked about the frequency of their alcohol intake pre-pregnancy, during the first trimester and during trimesters two and three (all categorical). Responses were on a scale of ‘no’; ‘yes every couple of months’; ‘yes once/twice a month’; ‘yes once/twice a week’ and ‘yes almost every day’. These variables were utilised within Chapter Three, only when outlining the behaviour of the cohort. Also, in line with existing research, data from the first trimester and trimesters two and three were combined to form the variable ‘alcohol at any point in pregnancy’ (categorical), which was scored ‘yes’ or ‘no’, and was the alcohol variable utilised throughout the thesis, when examining factors associated with alcohol consumption in Chapter Three and within all analyses in Chapters Four and Five. Participants noted to have consumed alcohol at any frequency during either trimester one and/or trimesters two and three were scored as ‘yes’ and those who abstained were scored as ‘no’.

Participants were also asked about their frequency of smoking cigarettes pre-pregnancy, during the first trimester and during trimesters two and three (all categorical). Responses were reported on a scale of ‘no’; ‘yes occasionally’ and ‘yes daily’. These variables were utilised within Chapter Three, only when detailing the cohort behaviour. As with alcohol and in line with existing research, data from trimester one and trimesters two and three were combined to form the variable ‘smoking at any point in pregnancy’ (categorical), again scored as ‘yes’ or ‘no’, and was the smoking variable utilised throughout the thesis, when investigating factors associated with smoking in Chapter Three and within all analyses in Chapters Four and Five. Participants who reported smoking at any frequency during either trimester one and/or trimesters two and three were scored as ‘yes’ and those who reported no smoking at any timepoint were scored as ‘no’.

The questionnaire also included data on exercise, with participants asked if they undertook any exercise during pregnancy. This was defined as exercise undertaken for at least 30 minutes, at least once a week. A validated questionnaire was not utilised, instead the questionnaire item consisted of ‘Have you done any exercise during your pregnancy? E.g. running, jogging, squash, swimming, aerobics or football done for at least 30 minutes, at least once a week’ (categorical). This was a binary variable with responses of ‘yes’ or ‘no’ available.

Diet during pregnancy was measured within the questionnaire utilising a food frequency questionnaire (FFQ). This 17-item questionnaire was developed for use specifically for this cohort by a previous lab member, through consultation with and evaluation by a nutritionist with extensive practical experience of the typical dietary habits of pregnant women in South Wales. The FFQ was reviewed and evaluated for suitability by 10 women who were either pregnant or had recently given birth, before being piloted with 289 pregnant women. Participants were asked to rate the frequency of consumption of the various food items since becoming aware of the pregnancy on a five-point scale of ‘never/rarely’, ‘once in two weeks’, ‘two to three times per week’, ‘once per day’ and ‘more than once per day’ (categorical). This data was utilised in Chapter Three to derive dietary pattern variables (continuous).

2.1.3.1.3. Maternal mental health

The questionnaire incorporated the Edinburgh Postnatal Depression Scale (EPDS) (Cox et al., 1987), a measure that assesses self-reported maternal depressive symptoms, which has been validated for use in the antenatal period (Cox et al., 1996). A review by Kozinszky and Dudas (2015) identified sensitivity and specificity estimates ranging from 64%-100% and 73%-100% respectively. The EPDS is a 10-item questionnaire that requires participants to select from four possible responses, the answer that comes closest to how they have felt in the previous seven days. The maximum possible score is 30, with a score ≥ 13

indicative of probable depression (Cox et al., 1987, Matthey et al., 2006). This variable was utilised as both continuous, when considering total score, as well as categorical in regards to a score of above or below the threshold for clinical significance.

The questionnaire also included the trait subscale of the Spielberger State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1983), a measure that assesses self-reported trait anxiety symptoms. This has been validated for use in pregnancy (Meades and Ayers, 2011), with sensitivity and specificity estimates of 80.95% and 79.75% respectively (Grant et al., 2008). This is a 20-item questionnaire that assesses anxiety symptoms in general, rather than the current state. This was felt to be most appropriate for use with participants due to undergo an ELCS shortly. All items are rated on a four-point scale of 'almost never', 'sometimes', 'often' and 'almost always'. The maximum possible score on this subscale is 80, with a score of ≥ 40 recommended as indicative of clinically significant high anxiety symptoms (Barnett and Parker, 1985). This variable was utilised as both continuous, when considering total score, as well as categorical in regards to a score of above or below the threshold for clinical significance.

2.1.3.2. Midwife recorded notes

The research midwives involved in the study recruitment were able to complete a form with data from participants medical records. This form contained data on participants age (continuous) and weight at booking (continuous), which was utilised in conjunction with the height data on the questionnaire to calculate BMI at booking (continuous), alcohol intake (categorical: Yes/No) smoking during pregnancy (categorical: Yes/No), parity (categorical: Nulliparous/Multiparous) and mental health history (categorical: Yes/No). It also contained data on medical concerns related to pregnancy such as hypertension (categorical: Yes/No) and gestational diabetes mellitus (GDM) (categorical: Yes/No), as well as weight at delivery (continuous), mode of conception (categorical: Natural/Assisted), indications for ELCS (categorical: Previous caesarean section (CS)/Current pregnancy complications/Previous pregnancy complications/Maternal choice/Maternal mental health/Maternal health (non-pregnancy related)) and mode of delivery (categorical: ELCS/Emergency CS/Spontaneous vaginal delivery/Instrumental delivery). Mode of delivery was incorporated as despite participants being booked for an ELCS, a small minority of participants gave birth via different mode in the short time between the pre-operative assessment and the ELCS. Further, it incorporated data on the infant, including infant sex (categorical: Male/Female), birthweight (continuous and categorical: Low birthweight/Average birthweight/High birthweight) and gestational age (continuous). This data were utilised to calculate infant CBWC, via the GROW bulk centile calculator (UK) (Gardosi and Francis, 2016). The CBWC data was utilised as both continuous and categorical variables (Small for gestational age/Average for gestational age/Large for gestational age) in Chapters Three and Five.

Additionally, the midwife notes recorded the one and five minute APGAR scores. APGAR scores are a measure of a newborn infant's health status, based on heart rate, respiration, colour, muscle tone and reflex irritability (Apgar, 1952). The five categories each have possible scores of zero to two and when summed up there is a maximum total score of 10. Total scores between seven and 10 are considered within the 'normal' range, with scores below this typically associated with poor outcomes. However, recent research suggests a low score of seven to nine in the 'normal' range is also potentially a cause for concern and may be linked to sub-optimum outcomes (Razaz et al., 2019). As such this was investigated in Chapter Five as both a continuous variable (total score) and two categorical variables (nine or less/10 & seven-nine/10).

Finally, data on participants weight at delivery (continuous) was utilised in conjunction with participants pre-pregnancy weight (continuous) as recorded on the A1 questionnaire, in order to calculate gestational weight gain (GWG). This was incorporated into analyses both as a continuous variable as well as a categorical variable (Inadequate/Normal/Excessive) as defined by the Institute of Medicine (IOM) guidelines (Institute of Medicine, 2009).

2.1.4. Y1 timepoint

The Y1 timepoint involved data collection in the form of a questionnaire and laboratory based researcher led infant assessment. This allowed for the acquisition of both subjective and objective measures of infant development and temperament.

2.1.4.1. Questionnaire

2.1.4.1.1. General

The Y1 questionnaire collected general data which included maternal age (continuous), maternal weight (continuous), health issues (categorical:Yes/No), working status (categorical: Working/Not working) and infant age at questionnaire completion and assessment (continuous).

2.1.4.1.2. Temperament

The Cardiff Infant Contentiousness Scale (CICS) (Hay et al., 2010) was included in the Y1 questionnaire. The CICS was developed to assess early manifestations of anger in the form of the infants use of physical force against people in social interactions and expressions of anger. The CICS was designed to be embedded within an overall larger ‘distractor’ questionnaire examining normative developmental milestones. Whilst the overall questionnaire contains 25 items, the CICS within this is comprised of only six items. The specific items were angry moods, hits out at people, bites, temper tantrums, grabs toys and hits or kicks to get toys. Participants were required to rate the frequency of the infant behaviours on a three-point scale of ‘not yet’, ‘sometimes’ and ‘often’, scored as zero to two. There was a possible score of between zero and 12 with a higher score indicating higher levels of aggression (continuous). Missing data was previously addressed in the CICS by utilising participant level mean substitution for missing questionnaire items, for participants missing < 20% of data.

The Y1 questionnaire also incorporated the well-established Infant Behaviour Questionnaire (IBQ). The specific version utilised was the revised short form (IBQ-R-SF) (Putnam et al., 2014). The IBQ-R-SF examines infant temperament, up to one year of age, through maternal self-report. This questionnaire is widely used and has been validated in numerous settings. The IBQ-R-SF consists of 91 items, with participants asked to rate the frequency of specific temperament-related behaviours observed in their infant over the past week, using an seven-point scale of ‘not applicable’, ‘never’, ‘very rarely’, ‘less than half the time’, ‘about half the time’, ‘more than half the time’, ‘almost always’ and ‘always’, scored from one to seven (continuous). An option of ‘not applicable’ was also available, with this item left blank on data entry should it have been selected as per the IBQ manual. The IBQ-R-SF is designed to assess various dimensions of temperament. There are three major domains; surgency, negative affectivity and regulatory capacity. There are also 14 subdomains: activity level, distress to limitations, approach, fear, duration of orienting, smiling and laughter, vocal reactivity, sadness, perceptual sensitivity, high intensity pleasure, low intensity pleasure, cuddliness, soothability and falling reactivity/rate of recovery from distress. Definitions for each domain and subdomain are outlined in Table 2.1. Unfortunately, four questions from the soothability scale were inadvertently omitted during the Y1 questionnaire development, however, research utilising this data has nonetheless been successfully published (Savory et al., 2020) and it remains an effective measure of temperament. Only the main domains were utilised in this thesis. Missing data on the IBQ-R-SF was previously addressed in line with the IBQ manual and advice from the questionnaire developer. As the manual instructs that both ‘not applicable’ responses and missing items should be left blank on data entry this makes assessment of the level of missing data difficult. However, the manual and questionnaire developer recommend not distinguishing between the two types of ‘missing’ data or excluding participants with large levels of missing data, as the IBQ is robust against this. Due to the large number of subscales within the IBQ, item/variable level rather than participant level mean substitution was utilised for missing questionnaire items.

Table 2.1 Definitions of the domains of temperament on the IBQ. Adapted from https://research.bowdoin.edu/rothbart-temperament-questionnaires/instrument-descriptions/the-infant-behavior-questionnaire & Rothbart and Putnam (2002)

Domain	Definition
Surgency	An ‘approach’ domain characterised by impulsivity, low shyness, high activity level and intense pleasure seeking.
Negative affectivity	A domain characterised by angry reactivity, dysregulated negative emotions and mood instability.
Regulatory capacity	Characterised by the ability to maintain task attention and resist distraction whilst also refraining from a dominant or desired behaviour.
Activity level	Movement of arms and legs, squirming and motor activity.
Distress to limitations	Fussing, crying or showing distress while 1) in a confining position or place 2) involved in caretaking activities 3) unable to undertake a desired action.
Fear	Startle or distress to sudden changes in stimulation, novel physical objects or social stimuli. Inhibited approach to novelty.
Duration of orienting	Attention to and/or interaction with an object for extended periods of time.
Smiling and laughter	Smiling and/or laughter in general caretaking and play situations.
High intensity pleasure	Amount of pleasure or enjoyment related to high stimulus intensity, complexity, rate, incongruity and novelty.
Low intensity pleasure	Amount of pleasure or enjoyment related to situations involving low stimulus intensity, complexity, rate, incongruity and novelty.
Soothability	Reduction of distress, fussing or crying when the caretaker uses soothing techniques.
Falling reactivity/ rate of recovery from distress	Rate of recovery from peak distress, excitement or general arousal & the ease of falling asleep.
Cuddliness	Expression of enjoyment and moulding of the body to being held by a caregiver.

Domain	Definition
Perceptual sensitivity	Amount of detection of slight, low intensity stimuli from the external environment.
Sadness	General low mood. Lowered mood and activity related to personal suffering, physical state, object loss or inability to perform a desired action.
Approach	Rapid approach, excitement and positive anticipation of enjoyable activities.
Vocal reactivity	Amount of vocalisation exhibited in daily activities.

2.1.4.1.3. Maternal care

2.1.4.1.3.1. Breastfeeding

Data on breastfeeding was available from both the Y1 and Y4 questionnaires. Participants were asked if they breastfed their infant, with possible responses of ‘yes’ or ‘no’ (categorical). Data from the Y1 and Y4 questionnaires were combined to form a single breastfeeding variable. Participants were also asked to record the duration that they breastfed their infant (continuous). Data from both timepoints was again combined, with the variable recategorized to recognise if the breastfeeding duration met that recommended by the World Health Organisation. This categorical variable was also scored as ‘yes’ or ‘no’

2.1.4.1.3.2. Mother-Infant relationship

The Postpartum Bonding Questionnaire (PBQ) (Brockington et al., 2001) was incorporated within the Y1 questionnaire in order to assess maternally reported mother-infant bonding. The PBQ is a 25-item questionnaire in which participants are required to select a response that reflects their recent bonding experience from a six-point scale of ‘always’, ‘very often’, ‘quite often’, ‘sometimes’, ‘rarely’ and ‘never’. This questionnaire assesses bonding according to scores on four factors. Factor one identifies general problems with bonding, e.g. ‘I feel trapped as a mother’. Factor two focuses on rejection and pathological anger, e.g. ‘I feel angry with my baby’. Factor three assesses anxiety about the infant, e.g. ‘my baby makes me feel anxious’ and factor four addresses incipient abuse, e.g. ‘I feel like hurting my baby’. Due to the extreme nature of factor four, this factor and the two questions that it is composed of were not included in the Y1 questionnaire. Thus, in this context the PBQ is a 23-item questionnaire. Each questionnaire item is scored from zero to five with a maximum possible overall score of 115, with a higher score indicating higher levels of bonding problems (continuous). It is also possible to categorise the data as high or low risk. The thresholds for high-risk categories for the overall PBQ are scores ≥ 26, for factor one ≥

12, for factor two ≥ 16 and for factor three ≥ 9 (categorical: Above threshold/Below Threshold). Missing data was previously addressed in the PBQ by utilising participant level mean substitution for missing questionnaire items within the specific subscales, for participants missing < 20% of data.

2.1.4.2. Infant assessment

When the infants reached one year of age, participants were invited to attend a researcher led infant assessment. To enable the coding of behaviour, all assessments were undertaken by two trained researchers in a designated experimental testing room at Cardiff University and were recorded with permission from the participant.

2.1.4.2.1. Temperament

Infant temperament was assessed via tasks adapted from the Laboratory Temperament Assessment Battery (Lab-TAB) (Goldsmith and Rothbart, 1996). Data from the Novel Toy, Sustained Attention and Maternal Separation tasks were utilised for this thesis.

The Novel Toy task utilised an adapted version of the Mechanical Toy task within the Lab-TAB manual. In our assessment, the infants were sat in a small chair and a robot toy that had not previously been seen was brought into the room. The mothers were requested to sit behind the infant where they could not easily be seen and were asked not to interact with the infant. The robot toy was placed at a distance in front of them. The task consisted of three trials unless the infant became too distressed to continue. In each trial, the robot would walk towards the infant stopping approximately 20 cm from them, pause for 10 seconds, walk backwards to the starting point and pause for a further five seconds. Following the third trial the infant was given the opportunity to play with the robot. The outcomes measured on this task were intensity of facial fear, intensity of distress vocalisations, intensity of bodily fear, intensity of escape and the presence of startle response. These variables were all continuous and scored on a scale from zero (no response) to two (clear response), based on the Lab-TAB coding scheme.

The Sustained Attention task was adapted from the Repeated Visual Stimulation task in the Lab-TAB manual, with sustained attention measured utilising a carousel toy not previously seen by the infant. As with the Novel Toy task, the infant was sat in a small chair, with their mothers requested to sit behind the infant where they could not easily be seen and asked not to interact with them. If the child refused to sit in the chair, they were able to sit on their mother’s lap, as long as no interaction occurred. The carousel was positioned approximately 40 cm in front of the infant and was set to play for around 3 minutes. The task either ended after three minutes or sooner if the infant became distressed and it was not possible to measure attention accurately. The outcomes measured on this task were positive affect and negative affect (continuous) which were scored on a scale from zero (no affect displayed) to two (clear affect displayed) and based on the Lab-TAB coding scheme.

The assessment also included the Maternal Separation task. For this, mothers were instructed to leave the room in the manner in which they would usually do at home, for example either saying goodbye or walking out quietly. One researcher would leave the experimental room with the mother, entering another room where they could watch the infant. Another researcher would stay in the experimental room with the infant but not interact with them for the duration of the task, in which the infant had free range to play with any toy available to them in the room. The task continued for two minutes unless the infant became distressed or the mother wished to end the task. The outcomes measured on this task were intensity of facial fear, intensity of distress, intensity of bodily fear and intensity of escape response. These variables were all continuous and scored on a scale from zero (no response) to two (clear response). Latency to fear response was also included as an outcome, in which the infant was timed from the moment the mother left the room to the occurrence of a fear response (continuous). These outcomes and scoring were based on the Lab-TAB coding scheme.

Recordings of the three tasks were later coded by two independent researchers, utilising an adapted version of the LabTAB coding manual. Any discrepancies between the coding were discussed and resolved on mutual agreement. All coding was later rechecked as part of this PhD to ensure accuracy.

2.1.4.2.2. Neurodevelopment

The Bayley Scales of Infant Development Third Edition (BSID-III) (Bayley, 2009) was utilised to evaluate age-standardised cognition and expressive and receptive language development. It was developed for use in infants aged between one and 42 months. The cognitive scale assessed play skills, memory, information processing, reasoning abilities and habituation skills. The expressive language scale considered the ability to communicate wants, name objects and actions, use multi-word sentences and respond to questions. The receptive language scale measured the ability to discriminate between sounds in the environment and comprehend and respond to requests (Michalec, 2011). Each item on the scales was scored as either zero if the child was unsuccessful at the item, or one if they were successful. The infants age at the time of the assessment determined the start point for the item scoring. Language was assessed by the two researchers throughout the whole duration of the infant assessment. The cognitive scale was administered by one researcher and scored by two researchers. To evaluate cognition, participants were invited to sit at a table with their infant in the supported seated position facing forward on their mother’s lap. The cognitive scale involved the infant completing a series of tasks that incorporated a range of materials. The child must successfully complete the first task item at the start point for their age to proceed at that level for the assessment. If they are unsuccessful the tasks would begin at the start point for the previous age group. Administration and assessment of the cognitive task items would continue until the infant obtained a score of zero on four consecutive items. These scales were treated as continuous variables.

2.1.5. Y4 timepoint

2.1.5.1. Questionnaire development

The Y4 questionnaire (Appendix 1) was developed as part of this PhD to facilitate the collection of further data for the cohort. This questionnaire was designed to provide additional longitudinal data for measures utilised in previous data collection waves such as demographic data, the EPDS, STAI and FFQ, as well as to assess the infant’s continuing development with these specific questionnaires outlined shortly. In order to assess the acceptability of the questionnaire it was piloted with a population separate from the GiW cohort. Social media was utilised to recruit eight participants with a child aged four years to complete the Survey Monkey online questionnaire and respond with feedback regarding its suitability. Following feedback regarding the length of the questionnaire, it was shortened to ensure it was practical for the GiW participants to complete.

The GiW participants were invited to complete this questionnaire when their infant reached four years of age. Participants were able to complete the questionnaire either online via SurveyMonkey or via a posted paper copy.

2.1.5.2. General

The Y4 questionnaire recorded general data regarding the participant which included maternal age (continuous), maternal weight (continuous), working status (categorical: Yes/No/Maternity leave/Do not wish to say), family income before deductions (categorical: <£18,000/£18-25,000/£25-43,000/£>43,000/Do not wish to say), education level (categorical: Left before GCSE/GCSE/A-level/University/Postgraduate/Vocational/Do not wish to say), marital status (categorical: Married/In a relationship/Separated/Widowed/Divorced/Single/Do not wish to say), additional children (categorical: Yes/No/Do not wish to say) and health issues (categorical: Yes/No/Do not wish to say).

2.1.5.3. Temperament

The Child Behaviour Questionnaire – Short Form (CBQ-SF) is a continuation of the IBQ, developed to measure temperament in early childhood between the ages of three to seven years (Putnam and Rothbart, 2006). The CBQ-SF is a 94-item questionnaire in which participants are requested to reflect on their child's likely reaction to various situations, deciding whether each statement is reflection of their child's reaction within the past six months. Participants can respond on an seven-point scale of 'extremely untrue', 'quite untrue', 'slightly untrue', neither true nor false', 'slightly true', 'quite true' and 'extremely true', scored from one to seven (continuous). There is also an option to select 'not applicable' which is later scored zero and left blank on data entry. The CBQ-SF measures three main dimensions of temperament labelled negative affect, surgency/extraversion and effortful control, as well as 15 subdimensions. These subdimensions are: activity level, anger/frustration, approach, attentional focusing, discomfort, falling reactivity and soothability, fear, high intensity pleasure, impulsivity, inhibitory control, low intensity pleasure, perceptual sensitivity, sadness, shyness and smiling and laughter. Definitions of these domains are provided in Table 2.2. Only the main domains will be investigated in this thesis.

Table 2.2 Definitions of the domains of temperament on the CBQ. Adapted from https://research.bowdoin.edu/rothbart-temperament-questionnaires/instrument-descriptions/the-childrens-behavior-questionnaire & Rothbart and Putnam (2002)

Domain	Definition
Negative affectivity	Impulsivity, low shyness, high activity level and intense pleasure seeking.
Surgency/extraversion	Angry reactivity, dysregulated negative emotions and mood instability.
Effortful control	The ability to maintain task attention and resist distraction whilst also refraining from a dominant or desired behaviour.
Anger/frustration	Negative affect related to goal blocking or interruption of ongoing tasks.
Approach	Positive anticipation and excitement for expected pleasurable activities.
Attentional focusing	Tendency to maintain attentional focus on task related channels.
Discomfort	Negative affect related to sensory qualities of stimulation, including rate, complexity or intensity of movement, sound, texture and light.

Domain	Definition
Falling reactivity & soothability	Rate of recovery from excitement, peak distress or general arousal.
Fear	Negative affect, including nervousness, unease or worry related to anticipated distress or pain and/or potentially threatening situations.
High intensity pleasure	Enjoyment or pleasure related to situations involving high stimulus complexity, intensity, incongruity, rate and novelty.
Impulsivity	Speed of response initiation.
Inhibitory control	The capacity to plan and suppress inappropriate approach responses in novel or uncertain situations or under instruction.
Low intensity pleasure	Enjoyment or pleasure related to situations involving low stimulus complexity, intensity, incongruity, rate and novelty.
Perceptual sensitivity	Detection of slight, low intensity stimuli from the external environment.
Sadness	Negative affect and lowered energy and mood related to exposure to object loss, disappointment and suffering.
Shyness	Inhibited or slow approach in situations involving uncertainty or novelty.
Smiling & laughter	Positive affect in response to changes in stimulus incongruity, rate, complexity and intensity.

2.1.5.4. Behaviour

The Child Behaviour Checklist (CBCL) (Achenbach and Rescorla, 2001) was developed to assess parent reported behavioural and emotional problems. The Y4 questionnaire utilised the version applicable for children aged one and a half to five years. The CBCL is a 100-item questionnaire in which parents are required to reflect on their views of their child’s behaviour, now or within the last two months, even if other people might not agree. Responses are on a three-point scale of ‘not true’, ‘somewhat of sometimes true’ and ‘very true or often true’, with parents also invited to provide additional comments or descriptions to certain items. There are also three questions following the 100-items in which parents are encouraged to list if the child has any illnesses or disabilities, what concerns them most about the child and the best things about the child. Items can be scored according to syndrome scales and DSM-orientated scales. Syndrome scales include anxious/depressed, withdrawn/depressed, somatic complaints, social problems, thought problems, attention problems, rule breaking behaviour and aggressive behaviour. Certain scales can also be collated into internalising and externalising problems. DSM-orientated scales include affective problems, anxiety problems, somatic problems, attention deficit hyperactivity problems, oppositional defiant problems and conduct problems. Whilst data from this questionnaire is not utilised in this thesis, it will be utilised in future post-doctoral research.

2.1.5.5. Mother-child relationship

The Child-Parent Relationship Scale (CPRS) (Pianta, 1992) was developed to assess parent perceptions of their relationship with their child, validated for children aged three to 12 years (Driscoll and Pianta, 2011). This is a 30-item questionnaire in which the participant is required to reflect on the degree to which the statements apply to their current relationship. Possible responses are on a five-point scale ranging from 'definitely does not apply', 'not really', 'neutral, not sure', 'applies somewhat' and 'definitely applies'. The questionnaire was designed to measure three areas; conflict, closeness and dependence. The conflict subscale assesses the degree to which the parent perceives the relationship to be characterised by negativity, unpredictability, discordance and unpleasantness, with a maximum total score of 60. The closeness subscale measures the perception of a relationship characterised by open communication, affection and warmth, with a maximum total score of 50. Finally, the dependency scale denotes the perception of the relationship to be characterised by an inappropriate degree of possessiveness and overreliance, with a maximum total score of 20. All scale variables were treated as continuous.

2.1.6. Statistical analysis

Regarding participant inclusion, seven participants withdrew from the GiW cohort and thus their data were not incorporated into any analyses. Eligibility criteria was also applied to all analyses. A gestational age of ≥ 37 weeks at delivery was required as this is considered to be a term delivery. Participants were also required to be of Caucasian ethnicity in order to maintain sample homogeneity and reduce 'noise' (Bornstein et al., 2013), as this ethnicity constituted 91% of the cohort. This particular criterion will be discussed further in later sections. In addition to these criteria, analyses of Y1 data required infants to be aged <18 months of age, which was in line with previous research and was due to the established age restrictions of the measures utilised. Furthermore, analyses of both Y1 and Y4 data required the infants to have no serious diagnosed health or developmental conditions, as this would heavily impact on and confound any findings.

All analyses were undertaken utilising IBM SPSS Statistics Version 27. Statistics relevant for each aspect of the thesis are discussed in depth in each chapter. In terms of missing data, it was not necessary to address this for the majority of variables due to minimal 'missingness'. The method for addressing missing data in specific measures, such as the IBQ-R-SF, was previously outlined within this chapter. Briefly, normality was assessed through consideration of histograms, skewness, kurtosis, Kolmogorov-Smirnov and Shapiro-Wilk values. Dietary patterns were established utilising principal component analysis with orthogonal varimax rotation.

Associations between variables were assessed through unadjusted and adjusted linear or binary regression where appropriate. Model assumptions were checked throughout 1) Independence of residuals/observations was assessed via the Durbin-Watson statistic 2) Linearity was assessed via two methods a) Between dependent and independent variables 'collectively' using a scatterplot of the unstandardised predicted values and the studentised residuals b) Between the dependent variable and each independent variable (in this case only the dietary patterns as it is not necessary to do this for categorical variables) using partial regression scatter plots 3) Homoscedasticity of variance was assessed via a scatter plot of the unstandardised predicted values and the studentised residuals 4) Multicollinearity was assessed via tolerance and VIF statistics 5) Leverage was assessed via leverage values 6) Normal distribution of residuals was assessed via both a histogram and P-P plot of regression standardised residuals.

The unadjusted and adjusted models were conducted by two different methods:

1. Chapter Three, assessing factors associated with each health behaviour – The unadjusted model analyses here involve the demographic, biological and psychological independent variables being entered into the initial models in a univariable manner. The adjusted model analyses then incorporate any variables significant at $p < .05$ in the unadjusted model simultaneously, in a multivariable manner. The dependent variables in these analyses were the occurrence of the health behaviours
2. Chapter Three, Four and Five, assessing the influence of health behaviours on each outcome of interest – Here, the unadjusted initial models incorporate only the five health behaviours as independent variables, entered simultaneously in a multivariable manner. Should health behaviour variables within the initial unadjusted model be significant, relevant confounding variables are then incorporated to form an adjusted analysis and model, with all variables again entered in a multivariable manner. The dependent variables in these analyses were the maternal or infant outcome of interest.

Potential confounding variables that were incorporated within the second adjustment method were selected from the literature, previous GiW papers and occasionally through the peer review process. The confounding variables incorporated into each model are outlined in each chapter. Figures were produced via SPSS or Microsoft Excel.

2.1.7. General limitations

One potential limitation of the research within this thesis may arise when considering the retention and response rate within the cohort. Whilst the retention rate remained relatively high, with only seven participants actively withdrawing from the cohort, the response rate at the various data collection waves did vary. Indeed, the response rate varied across timepoints from 55% at the first follow-up, to 40% at the most recent data collection wave at Y4, although reassuringly this did increase from the previous wave. Despite the response rate reducing the availability of data, it was still possible to obtain interesting and insightful findings and, with the obvious exception of the extremely large multinational cohorts, the sample size remained similar to many of the studies in this area. Moreover, this is an issue that is highly prevalent in longitudinal cohort research (Ployhart and Vandenberg, 2010, Plewis, 2007) and is not unique to this thesis.

As discussed, the research within this thesis begins to address the paucity of research conducted in Wales. Whilst data collected on participant postcodes indicated that participants lived in a large range of areas, it is true that recruitment only focused on one hospital. Consequently, this research only incorporated the Cardiff region and Cardiff and Vale Health Board in South-East Wales. It was previously highlighted in Chapter One that there are health and socioeconomic disparities across Wales, with reports highlighting differences in health outcomes, such as birthweight, across areas. As such, although the thesis provides an important role in addressing the paucity of evidence, further research should cover a range of areas to ensure findings are appropriate for and generalisable to the whole of Wales.

Research of this nature, or cohort studies, generally have a recognisable demographic. That is, participants are typically Caucasian, have high education and income levels and generally have good socioeconomic status. It will be seen in Chapter Three that within the GiW cohort participants do appear to follow this trend. However, there is still a range of education and income levels present, not simply the highest levels and, in the case of WIMD score (the Welsh measure for deprivation) there are participants in the cohort from across the spectrum from highest to lowest deprivation. As such, the GiW cohort covers a range of participant demographics and thus it is felt that this general limitation of cohort studies is minimised in regards to this research. It should, however, be noted that there is a difference in demographic characteristics across the data collection timepoints. For example, at A1 there were 9.00% of participants in the lowest income category, whilst at Y4 this increased to 25.40%. Although this is likely to be partly influenced by the decreased participation at later timepoints, this does have the potential to have influenced findings. As such, this difference in cohort demographics should be taken into account when considering the findings of this thesis.

A limitation of this cohort may also relate to the mode of delivery. Participants were invited to participant if records indicated that they were due to undergo an ELCS. This was selected to optimise the collection of biological samples, such as placenta, which was the original focus of the cohort. It could be suggested that this focus on ELCS could make the cohort different to the general population. This was addressed in the first paper published from the cohort, which investigated the differences between the cohort population and the overall population giving birth at UHW (N = 7600) during the same period (Janssen et al., 2018). It was determined that overall the two populations were very similar, with differences only identified in age, parity and BMI. Specifically, participants within the GiW cohort were slightly older (mean = 33 vs 30) with a slightly higher BMI (mean = 26 vs 25) and were more likely to be multiparous than the general population. Thus, the differences can be considered minimal. Moreover, numerous publications have resulted from the GiW cohort, with findings similar to a range of different study populations. Thus, it is felt that this influence of this discussion point and cohort characteristic is minimal.

Another possible limitation of the research within this thesis is the decision to focus solely on Caucasian participants. This selection criteria could reduce the generalisability of the research as the findings may not be directly applicable to other ethnicities. However, this decision was felt most appropriate for this research as the GiW cohort consists of 91% Caucasian participants. The remaining 9% comprise of a range of different ethnicities with only low participant numbers in each. Consequently, incorporating only Caucasian participants ensured the minimisation of heterogeneity within the sample, as including the small number of other ethnicities would have introduced ‘noise’ which had the potential to negatively impact findings (Bornstein et al., 2013). Moreover, early work from the GiW cohort identified that inclusion of the small number of participants with different ethnicities heavily confounded the identification of factors associated with perinatal mental health, which were identifiable in only Caucasian participants despite the smaller sample size (Janssen et al., 2018). Additionally, it was originally planned that this thesis would incorporate gene expression analysis for which it is vital that heterogeneity is minimised.

Consequently, overall it was felt necessary for the purpose of this thesis to consistently focus on this particular demographic. Nevertheless, further research should be taken to investigate this area with the full participant sample for clarity.

This thesis contains multiple analyses and as such the possibility of an issue arising from multiple comparisons needs to be addressed. It was felt unnecessary to correct for this possibility for a number of reasons, all supported by influential published arguments within the statistical field (Althouse, 2016, Saville, 1990, Rothman, 1990, Gelman et al., 2012, Perneger, 1998, Feise, 2002). Firstly, it has been established that correction for multiple comparisons is not automatically necessary in research and is often inappropriately utilised. Indeed, it has been argued that this correction actually leads to an increase in Type 2 errors, increasing the likelihood of misinterpretation errors. Moreover, it was felt that correction was not required as the hypotheses of the thesis were clearly defined, with all analyses decided upon and planned in advance and selected on the basis that they best addressed the outlined hypotheses. All sections of the thesis addressed different outcomes but the same overall hypotheses and were treated as separate research studies. Additionally, the analyses were all similar and complimentary and importantly no additional analyses were undertaken that deviated from the initial plan after seeing the results. As these are all arguments that are emphasised in the literature highlighted above, it was felt that overall correction for multiple comparisons was not required. However, it may be conceded that the section of the thesis on temperament outcomes might benefit from correction. This is because unlike other sections, multiple measures were utilised to investigate an overall outcome. Whilst this section resulted in findings that were similar to previous research, it may provide reassurance and strength to this particular finding if correction was undertaken. Thus, future research could investigate if correction for multiple testing is influential for this outcome within the GiW cohort. Nevertheless, for the reasons outlined it was felt that overall multiple testing was not a limitation in this research and correction was not required.

With the exception of the midwife notes and Y1 assessments, the majority of the measures were self-report. Research has shown that this can come with limitations as self-report can be influenced by social desirability bias, which can impact results (Arnold and Feldman, 1981, Van de Mortel, 2008). However, in some areas self-report data may be more accurate. This will be seen in this thesis when considering the discrepancy in the reporting of alcohol during pregnancy, with the higher prevalence identified in the self-report questionnaire compared to the midwife recorded notes. Moreover, self-report can provide an understanding of the participants subjective compared to objective observed experience which can be valuable (Condon and Corkindale, 1998). For example, in research conducted on the GiW cohort, mothers perceptions of their infants temperament differed to that observed in the objective lab-based assessments, providing valuable insight that would not otherwise have been detected (Savory et al., 2020). Finally, self-report measures are less time consuming to complete and are considered appropriate for use in larger cohort studies, especially when longitudinal in nature with repeated measures (Streiner et al., 2015, Wittkowski et al., 2020). Thus, self-report measures have created valuable data within the GiW cohort and this thesis.

It should be considered that, as with all research, the analyses were limited to the data that has been collected within the cohort. Whilst the GiW cohort contains a wealth of data covering a range of areas and care was taken to attempt to collect all relevant data, there are naturally still areas that our data collection did not cover. For example, data were not collected on breastfeeding intention, which we are now aware is a factor influencing breastfeeding initiation. As such, although great lengths were taken to adjust all analyses for potential confounding, it is possible that there are factors we have not been able to control which may have influenced our findings. Nevertheless, whilst this should be taken into consideration, it does not detract from the importance of this research. Moreover, it is important to note that as with all research of this nature, that is, observational cohort studies, the findings reflect only associations and not specific causality. Indeed, the only way to begin to determine causality is via randomised control trial (RCT) studies. This research does nevertheless provide important enhanced understanding of both the nature of prenatal health behaviours and their influence on a range of outcomes in Wales. In the future this could form the basis upon which RCTs could be developed to determine specific causality in Wales. A similar point arises when considering the statistical modelling approach taken with this thesis.

Throughout, regression modelling was utilised to assess the influence of health behaviours on various outcomes. However, limitations may arise due to this approach. For example, as previously discussed this approach cannot determine causality, only associations. Additionally, the number of terms included in the model should be minimal due to the risk of overfitting the model, and there are multiple assumptions that need to be met before conducting any analyses. Nevertheless, there are a wide range of advantages of utilising this modelling approach. This is the approach that is overwhelmingly used in research within this field, ensuring that other researchers will easily understand any findings. Moreover, in comparison to other research, which tended to not effectively adjust analyses, all models significant at the unadjusted level were adjusted for potential confounders. These confounders were carefully selected to ensure only essential variables were incorporated to minimise the risk of over fitting the model. It was also ensured that the model assumptions were checked and met throughout. Furthermore, unlike previous research the approach taken was to investigate the influence of multiple health behaviours simultaneously, which as discussed throughout was a key previous omission. Thus, despite the limitations that naturally arise from regression modelling, it was strongly felt that this was the appropriate methodology for this thesis.

The limitations of the current research have been discussed, however it is important to note that many of the limitations outlined are highly prevalent in research, especially longitudinal cohort studies, and are not unique to this thesis or GiW cohort. They do not greatly detract from the importance of this research in addressing the gaps in the existing literature. Instead, as with all research, these points should be taken into account when considering research with an open and critical approach.

Chapter 3 - Health behaviours in the Grown in Wales cohort

3.1. Introduction

Health behaviours undertaken during pregnancy have important implications for the health and development of both mother and child. This is due to the influence they may have on the pregnancy environment. As previously emphasised, it is important to investigate these particular environmental influences due to their potential for modification through targeted intervention and guidance. However, before the influence of a range of maternal and infant outcomes can be investigated, it is vital to fully understand the nature of these prenatal health behaviours on a population. Whilst smoking rates at booking appointments in Wales are published in annual government reports, data on prenatal alcohol consumption, exercise and dietary patterns is less readily available. Indeed, it was not possible to identify any reports or previous studies in Wales that have investigated either the prevalence or characteristics of these behaviours, or factors that may predict their occurrence. Thus, the nature of prenatal health behaviours in Wales is largely unclear.

This chapter seeks to contribute to the current knowledge base by providing an understanding of the prenatal health behaviours that occur in a Welsh population. In doing so, it will address the first research question of this thesis: What are the health behaviours undertaken in pregnancy by women in Wales? Establishing answers to this question will enable the proposed hypotheses to be explored in subsequent chapters. To explore this area, this chapter will utilise Aim one of this thesis.

Aim 1. To understand the nature of the maternal health behaviours undertaken in pregnancy within the Grown in Wales cohort.

- To assess the frequency of smoking, alcohol intake and exercise in pregnancy.
- To establish the factors associated with each of the identified health behaviours.
- To determine the dietary patterns present during pregnancy.
- To consider the factors related to the derived maternal dietary patterns.
- To establish the suitability of and validate the dietary patterns by testing against an outcome i.e. infant birthweight.

3.2. Method

3.2.1. Participants

The recruitment procedure for the Grown in Wales (GiW) cohort has been previously outlined in Chapter Two. With the exception of seven participants who withdrew from the GiW cohort, 348 were initially eligible for inclusion in the analyses. Further eligibility criteria for inclusion required a gestational age of ≥ 37 weeks which is considered a term delivery and for participants to be of Caucasian ethnicity, to maintain the homogeneity of the sample and reduce “noise” (Bornstein et al., 2013). In light of this criteria, 312 participants were eligible for inclusion in the analyses within this chapter. Due to the slight variation in the availability of data and to ensure clarity, the specific participant numbers involved in each analysis is outlined at the start of each results subsection.

3.2.2. Materials

The materials have been outlined in depth in Chapter Two. Health behaviour data in the form of alcohol consumption, smoking, exercise and diet during pregnancy was extracted from the A1 questionnaire, completed at recruitment by the mother. The smoking and alcohol variables of trimester one and trimesters two and three were transformed into the variables “smoking at any point in pregnancy” and “alcohol at any point in pregnancy” with possible responses of ‘yes’ or ‘no’. The original variables (categorical) were utilised only to outline the behaviour within the cohort. The “at any point in pregnancy” variables (categorical) were utilised throughout the rest of this chapter and thesis, when examining factors associated with smoking and alcohol consumption as well as when examining the influence of said behaviours on further outcomes. Data on alcohol intake and smoking during pregnancy were also obtained from the midwife recorded notes (categorical: Yes/No). Data regarding diet was obtained from the 17-item food frequency questionnaire (FFQ), outlined in detail in the Chapter Two. Briefly, the FFQ required participants to rate the frequency of food item consumption since becoming aware of the pregnancy, with frequency recorded on a five-point scale as ‘never/rarely’, ‘once in two weeks’, ‘two to three times per week’, ‘once per day’ and ‘more than once per day’. The FFQ data were utilised to generate the dietary patterns (continuous) within the cohort.

Data on sociodemographic variables was also collected from the A1 questionnaire. This included the original education level (categorical: Left before GCSE/GCSE or vocational/A-levels/University/Postgraduate) and family income (categorical: <£18,000/£18-

25,000/£25-43,000/Do not wish to say) variables, whilst Welsh Index of Multiple Deprivation (WIMD) scores (continuous) were generated from participants postcodes. Additionally, biological variables such as diagnoses of gestational diabetes (GDM) (categorical: Yes/No) and pregnancy related hypertension (categorical: Yes/No), maternal age (continuous), parity (categorical: Nulliparous/Multiparous), height (continuous), maternal body mass index (BMI) at booking (continuous & categorical: Underweight/Healthy/Overweight/Obese), conception (Categorical: Natural/Assisted), gestational age at delivery (continuous), indications for elective caesarean section (ELCS) (categorical: Previous caesarean section (CS)/Current pregnancy complications/Previous pregnancy complications/Maternal choice/Maternal mental health/Maternal health (non-pregnancy related)) and mode of delivery (categorical: ELCS/Emergency CS/Spontaneous vaginal delivery/Instrumental delivery) were obtained from the midwife recorded notes. Custom birthweight centiles (CBWC) (continuous & categorical: Small for gestational age (SGA)/Average for gestational age (AGA)/Large for gestational age (LGA)) were calculated from data obtained from the midwife recorded notes on maternal ethnicity (categorical: Caucasian/Non-Caucasian), parity (categorical: Nulliparous/Multiparous), weight (continuous) and height (continuous) as well as infant gender (categorical: Male/Female), gestational age (continuous) and birthweight (continuous). This utilised the GROW bulk centile calculator (UK) (Gardosi and Francis, 2016). Participant data from the follow-up timepoints was obtained from the Y1 and Y4 questionnaires.

3.2.3. Statistical analysis

Normality for continuous demographic variables was assessed through consideration of histograms, skewness, kurtosis, Kolmogorov-Smirnov and Shapiro-Wilk values. All relevant variables were considered to be non-parametric. Friedman’s test was utilised to assess the differences between both smoking frequency and alcohol consumption between pre-pregnancy, trimester one and trimesters two and three. McNemar’s test was undertaken in order to assess potential differences in the reporting of alcohol intake and smoking between the A1 questionnaire and midwife recorded notes.

Dietary patterns were generated from the FFQ data, with the process outlined in Garay et al. (2019). Briefly, participants missing five or more responses on the FFQ were excluded from the analysis, whilst the missing responses for participants with four or less omissions were imputed as ‘never/rarely’. Principal component analysis (PCA) with orthogonal varimax rotation was utilised to establish *a posteriori* dietary patterns from the

FFQ data. Consideration of the scree plot, Kaiser criterion, factor loadings, simplicity and interpretability criteria were utilised to determine the appropriate number of components to derive, with subjective judgements of these criteria required. These are the criterion predominantly utilised in research to determine components (Moeller et al., 2007). An exploratory PCA was initially undertaken, involving all possible components followed by the assessment of solutions with specific component numbers to determine suitability, according to the above criterion. Food items with factor loadings of ≥ 0.30 or ≤ -0.30 were considered to be strongly associated with a component (Northstone et al., 2007). Once the final dietary pattern solution had been determined, dietary pattern scores were generated for each participant via the regression method to enable further analysis.

Unadjusted and adjusted binary regression was utilised to establish the variables associated with alcohol at any point in pregnancy, smoking at any point in pregnancy, exercise and both dietary patterns. This purposefully does not include outcome variables that will be investigated within Chapters Four and Five of this thesis. This utilised method one as outlined in section 2.1.6. Model assumptions as outlined in Chapter Two were assessed and found to not be violated. Associations between variables were initially assessed at the univariable level, which is considered to be the unadjusted model, with those significant at $p < .05$ included in an adjusted multivariable regression analysis, after assessing for multicollinearity via correlation coefficients or VIF and tolerance scores as relevant. Here, the independent variables were the demographic, biological and psychological variables, whilst the dependent variables were the health behaviours.

Dietary patterns were also assessed against an outcome to further confirm their suitability. Birthweight outcomes were selected for the assessment due to the large body of literature suggesting there may be an association between dietary patterns and birthweight, as discussed in Chapter One. The association between dietary patterns and overall CBWC was assessed utilising linear regression analysis. The association between dietary patterns and SGA compared to AGA and AGA compared to LGA were assessed by binary regression analyses. In these analyses dietary patterns were entered together in a multivariable format. These analyses were undertaken utilising both unadjusted models and models adjusted for potential confounders identified from the literature and through the peer review process. The potential confounders were maternal age, smoking during pregnancy, alcohol during pregnancy, exercise, GDM, conception and WIMD score. The models in these analyses utilise method two as outlined in section 2.1.6. Model assumptions as outlined in Chapter

Two were assessed and found to not be violated. Here, the independent variables were the five health behaviours (unadjusted model) and the five health behaviours and confounding variables (adjusted model), whilst the dependent variables were the CBWC outcomes.

3.3. Results

3.3.1. Grown in Wales cohort

Demographic data were available for participants within the cohort at the A1, Y1 and Y4 timepoints. Data are displayed in Table 3.1 and Table 3.2 for both the whole GiW cohort and Caucasian participants, which were the focus of the thesis. Categorical data are outlined as % (n) and continuous data as median (IQR), as this data were determined to be non-normally distributed.

Table 3.1 Demographic data for participants at the A1 timepoint

	Whole cohort	Caucasians
	% (n) or median (IQR)	% (n) or median (IQR)
Sample size (N)	348	316
Maternal height (m)	1.63 (.11)	1.64 (.11)
Maternal BMI at booking - overall	26.28 (7.28)	26.16 (7.06)
Maternal BMI at booking *% (n)*		
Underweight	1.60 (5)	1.00 (3)
Healthy	37.50 (120)	38.70 (115)
Overweight	35.00 (112)	35.00 (104)
Obese	25.90 (83)	25.30 (75)
Maternal age at booking	33.00 (6.00)	33.00 (6.00)
Ethnicity *% (n)*		
Caucasian	90.80 (316)	-
Other	9.20 (32)	-
Parity, *% (n)*		
Multiparous	80.40 (279)	79.40 (251)
Nulliparous	19.60 (68)	20.60 (65)
Gestational weight gain (kg)	14.80 (7.99)	14.84 (8.00)
Gestational diabetes mellitus *% (n)*		
Yes	5.70 (19)	4.60 (14)
No	94.30 (317)	95.40 (293)
Pregnancy related hypertension *% (n)*		
Yes	3.20 (11)	4.60 (14)
No	96.80 (332)	95.40 (293)
Indications for ELCS, *% (n)*		
Previous CS	55.10 (184)	53.80 (163)
Current pregnancy complications	21.30 (71)	22.10 (67)
Previous pregnancy complications	15.90 (53)	16.20 (49)
Maternal choice	3.30 (11)	3.60 (11)
Maternal mental health	0 (0)	0 (0)
Maternal health (non-pregnancy related)	4.50 (15)	4.30 (13)
Mode of delivery, *% (n)*		
ELCS	97.10 (335)	96.80 (304)
Emergency CS	.30 (1)	.30 (1)
Spontaneous vaginal delivery	2.30 (8)	2.50 (8)
Instrumental	.30 (1)	.30 (1)
Gestational age at delivery (weeks)	39.00 (.00)	39.00 (.00)

	Whole cohort	Caucasians
	% (n) or median (IQR)	% (n) or median (IQR)
Fetal sex, *% (n)*		
Female	54.70 (188)	55.00 (172)
Male	45.30 (156)	45.00 (141)
Custom birthweight centile	58.30 (49.60)	57.40 (50.25)
Size for gestational age *% (n)*		
SGA	7.00 (24)	7.30 (23)
AGA	79.10 (272)	78.60 (246)
LGA	14.00 (48)	14.10 (44)
Highest education level, *% (n)*		
Left before GCSE	5.80 (19)	6.30 (19)
GCSE & Vocational	23.30 (77)	24.50 (74)
A-level	12.40 (41)	13.20 (40)
University	32.40 (107)	30.10 (91)
Postgraduate	26.10 (86)	25.80 (78)
Family income (£), *% (n)*		
<18,000	9.00 (30)	8.60 (26)
18 – 25,000	10.20 (34)	9.20 (28)
25-43,000	19.20 (64)	20.40 (62)
>43,000	48.60 (162)	50.00 (152)
Do not wish to say	12.90 (43)	11.80 (36)
Conception, *% (n)*		
Natural	95.60 (324)	95.50 (297)
Assisted	4.40 (15)	4.50 (14)
A1 EPDS total	7.00 (6.00)	7.00 (6.00)
A1 STAI total	34.00 (13.00)	34.00 (13.00)
WIMD score	1216.50 (1242.25)	1268.50 (1218.25)

Table 3.2 Demographic data for participants at the Y1 and Y4 timepoints

Timepoint		Whole cohort	Caucasians
		% (n) or median (IQR)	% (n) or median (IQR)
Y1	Sample size (N)	126	116
	Maternal age	36.00 (7.00)	36.00 (7.00)
	Maternal weight (kg)	67.00 (17.20)	67.50 (17.42)
	Health issues *% (n)*		
	Yes	25.80 (32)	25.20 (29)
	No	74.20 (92)	74.80 (86)
	Working status *% (n)*		
	Working	80.60 (100)	81.70 (94)
	Not working	19.40 (24)	18.30 (21)
	Infant age (months)		
	Questionnaire	12.00 (1.00)	12.00 (1.25)
	Assessment	13.00 (2.00)	13.00 (2.00)
Y4	Sample size (N)	142	131
	Maternal age	39.00 (7.00)	38.00 (6.50)
	Maternal weight (kg)	68.95 (22.22)	68.95 (21.71)
	Working status *% (n)*		
	Yes	85.20 (121)	84.70 (111)
	No	11.30 (16)	11.50 (15)
	Maternity leave	2.10 (3)	2.30 (3)
	Do not wish to say	1.40 (2)	1.50 (2)
	Family income (£), *% (n)*		
	<18,000	25.40 (36)	25.20 (33)
	18 – 25,000	14.10 (20)	14.50 (19)
	25-43,000	31.00 (44)	32.10 (42)
	>43,000	23.90 (34)	22.90 (30)

Timepoint	Whole cohort	Caucasians
	% (n) or median (IQR)	% (n) or median (IQR)
Do not wish to say	5.60 (8)	5.30 (7)
Highest education level, *% (n)*		
Left before GCSE	0 (0)	0 (0)
GCSE	9.90 (14)	10.70 (21)
A-level	14.80 (21)	16.0 (21)
University	33.80 (48)	35.10 (46)
Postgraduate	34.50 (49)	31.30 (41)
Vocational	6.30 (9)	6.10 (8)
Do not wish to say	0.70 (1)	.80 (1)
Marital status *% (n)*		
Married	74.60 (106)	74.80 (98)
Separated	2.10 (3)	2.30 (3)
In a relationship	19.00 (27)	19.10 (25)
Widowed	0 (0)	0 (0)
Divorced	1.40 (2)	1.50 (2)
Single	2.10 (3)	2.30 (3)
Do not wish to say	0.70 (1)	0 (0)
Additional children *% (n)*		
Yes	18.60 (26)	18.60 (24)
No	84.40 (114)	81.40 (105)
Do not wish to say	0 (0)	0 (0)
Health issues *% (n)*		
Yes	24.30 (34)	23.30 (30)
No	75.00 (105)	76.70 (99)
Do not wish to say	0.70 (1)	0 (0)

3.3.2. Health behaviours

3.3.2.1. Alcohol

The frequency of alcohol consumption at various timepoints as recorded in the A1 questionnaire are displayed in Figure 3.1. Prior to pregnancy, eight (2.60%) participants reported drinking alcohol almost every day, 95 (30.70%) once or twice a week, 90 (29.10%) once or twice a month, 52 (16.80%) every couple of months and 64 (20.70%) never drank alcohol. This changed in pregnancy, with drinking alcohol in trimester one reported as two (.70%) drinking alcohol almost every day, 15 (4.90%) once or twice a week, 28 (9.20%) once or twice a month, 30 (9.80%) every couple of months and 230 (75.40%) never drinking alcohol. During trimesters two and three, zero participants reported drinking alcohol almost every day, seven (2.30%) once or twice a week, 23 (7.60%) once or twice a month, 50 (16.50%) every couple of months and 223 (73.60%) never drank alcohol. When the variables for alcohol intake in pregnancy were combined, 116 (38.20%) consumed alcohol at any point during pregnancy, whilst 188 (61.80%) consumed no alcohol during pregnancy. Friedman's test identified that overall, there were significant differences in alcohol consumption between timepoints ($p < .001$). Specifically, significant differences were identified between both trimester one and pre-pregnancy ($p < .001$) and trimesters two and three and pre-pregnancy ($p < .001$).

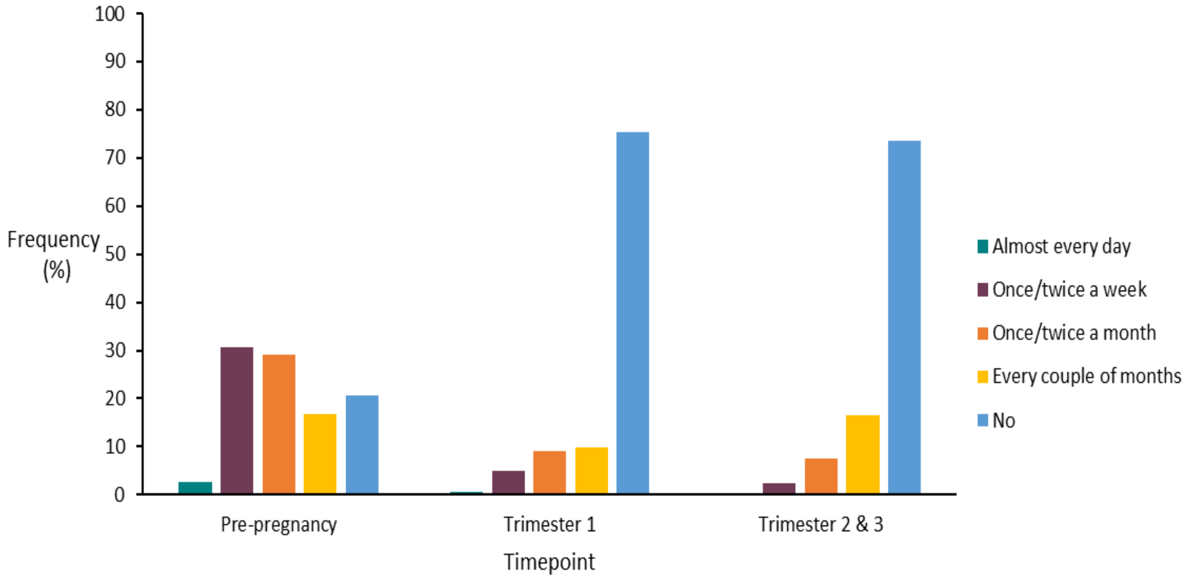


Figure 3.1 The frequency of alcohol consumption pre-pregnancy, during trimester one and during trimesters two and three

Alcohol intake was also recorded in the research midwife notes. Here, 298 (96.4%) reported consuming no alcohol in pregnancy, whilst only 11 (3.6%) reported consuming alcohol (Figure 3.2). McNemar's test confirmed that this was significantly different from the self-reported alcohol consumption on the questionnaire ($p < .001$).

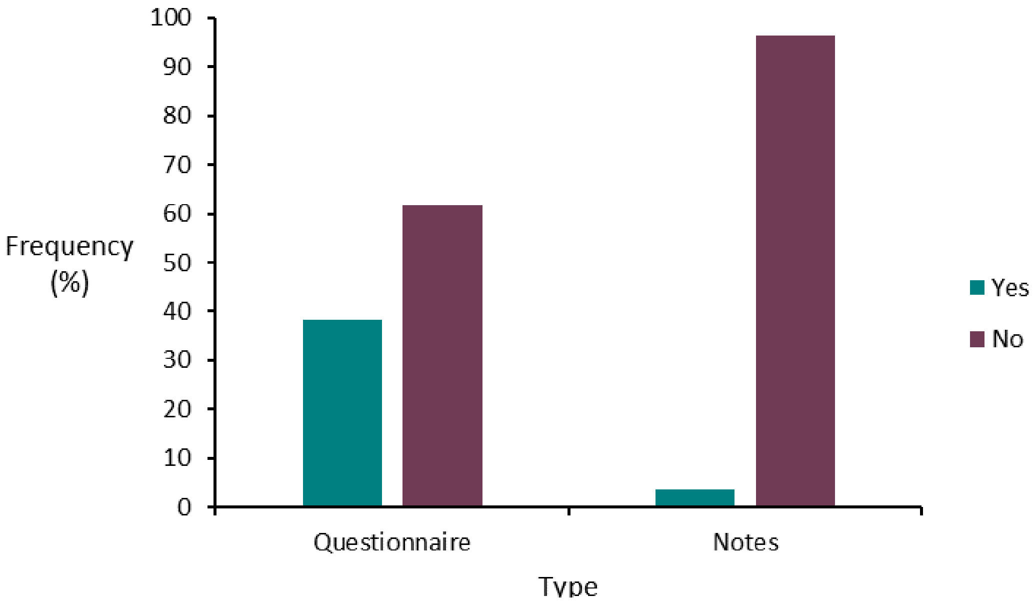


Figure 3.2 The frequency of alcohol intake as recorded on the A1 questionnaire & midwife recorded notes

From this point on the research will focus on the variable 'alcohol at any point in pregnancy' which is based on data from the questionnaire, as this is in line with the vast majority of health behaviour research, and guidelines recommend no alcohol during pregnancy. Binary regression was utilised to assess potential variables associated with alcohol intake during pregnancy. This does not include outcome variables that will be investigated within Chapters Four and Five of this thesis. At the univariable level (Table 3.3), maternal age at booking, a highest education level of 'Left before GCSE' compared to 'University', an income of < £18,000 and £18 – 25,000 compared to > £43,000, undertaking exercise and WIMD score were significantly associated with alcohol at any point in pregnancy. These variables significant at $p < .05$ at the univariable level were considered for inclusion in the adjusted multivariable binary regression. Correlation coefficients between the variables were assessed and multicollinearity deemed not to be present. At the adjusted multivariable level (Table 3.4), χ^2 (11) = 25.10, p = .009, only income remained significantly associated with alcohol, with an income of < £18,000 compared to > £43,000 reducing the odds of consuming alcohol at any point in pregnancy by a factor of .23.

Table 3.3 Unadjusted binary regression identifying variables associated with alcohol consumption at any point in pregnancy

	p	Exp (B)	95% CI
Fetal sex			
Female	*ref*		
Male	.428	1.21	.76, 1.92
Maternal BMI at booking	.878	1.00	.96, 1.05
Maternal age at booking	**.001**	1.08	1.03, 1.14
Parity			
Multiparous	*ref*		
Nulliparous	.627	.87	.48, 1.55
Gestational Diabetes (GDM)			
No	*ref*		
Yes	.805	.87	.28, 2.66
Hypertension			
No	*ref*		
Yes	.697	1.31	.34, 4.96
Highest education level			
Left before GCSE	**.030**	.24	.06, .87
GCSE & Vocational	.103	.58	.30, 1.12
A-level	.051	.44	.19, 1.00
University	*ref*		
Postgraduate	.365	1.33	.72, 2.47
Family income (£)			
<18,000	**.003**	.15	.04, .52
18 – 25,000	**.008**	.25	.09, .70
25-43,000	.279	.71	.39, 1.31
>43,000	*ref*		
Do not wish to say	.218	.62	.29, 1.32
Conception			
Natural	*ref*		
Assisted	.574	-.08	-.35, .19
Smoking in pregnancy			
No	*ref*		

	p	Exp (B)	95% CI
Yes	.943	.97	.46, 2.07
Exercise			
No	*ref*		
Yes	**.045**	1.86	1.01, 3.41
WIMD score	**.028**	1.00	1.00, 1.00

Table 3.4 Adjusted binary regression identifying variables associated with alcohol consumption at any point in pregnancy

	p	Exp (B)	95% CI
Maternal age at booking	.196	1.04	.98, 1.11
Highest education level			
Left before GCSE	.626	.69	.15, 3.08
GCSE & Vocational	.677	.85	.39, 1.83
A-level	.142	.51	.21, 1.25
University	*ref*		
Postgraduate	.586	1.20	.63, 2.28
Family income (£)			
<18,000	**.042**	.23	.05, .95
18 – 25,000	.210	.48	.15, 1.52
25-43,000	.584	.83	.43, 1.61
>43,000	*ref*		
Do not wish to say	.372	.65	.25, 1.68
Exercise			
No	*ref*		
Yes	.219	1.52	.78, 2.95
WIMD score	.672	1.00	1.00, 1.00

3.3.2.2. Smoking

Smoking frequency at the various timepoints is displayed in Figure 3.3. In the A1 questionnaire, prior to pre-pregnancy, 41 (13.30%) of participants reported smoking daily, 18 (5.80%) occasionally and 250 (80.90%) did not smoke. During the first trimester, 22 (7.10%) smoked daily, 11 (3.60) occasionally and 276 (89.30) reported not smoking. During trimesters two and three, only 19 (6.20%) smoked daily, five (1.60%) occasionally and 283 (92.20%) did not smoke at all. Finally, when the data from across pregnancy was combined, 34 participants (11.00%) smoked at any point in pregnancy, whilst 274 (89.00%) did not. Friedman's test identified overall significant differences in smoking frequency between timepoints ($p < .001$), specifically between pre-pregnancy and trimesters two and three ($p < .017$).

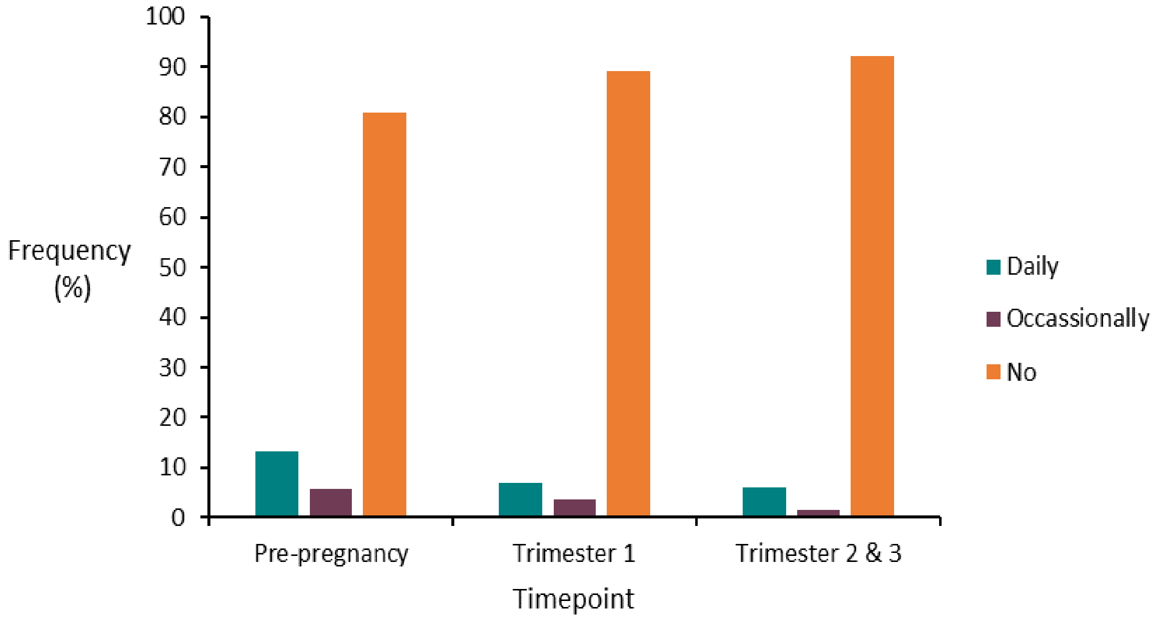


Figure 3.3 The frequency of smoking pre-pregnancy, during trimester one and during trimesters two and three

Again, smoking frequency was also measured on midwife recorded notes. Here, 286 (92%) participants recorded not smoking in pregnancy, whilst 25 (8%) of participants did smoke (Figure 3.4). There was a significant difference between the questionnaire and midwife recorded responses, assessed utilising McNemars test (p = .022).

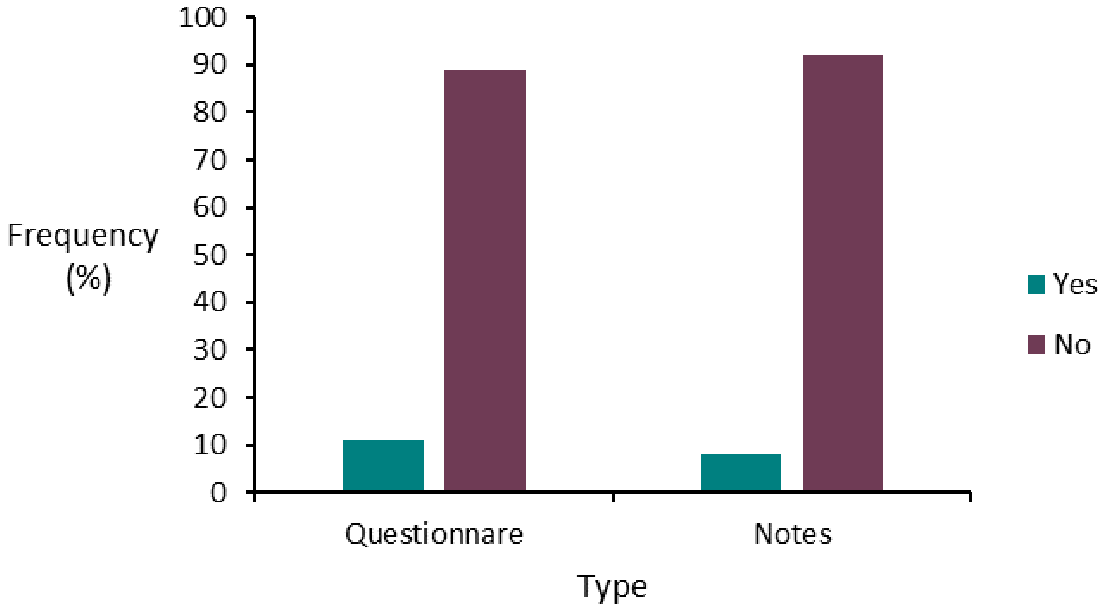


Figure 3.4 The frequency of smoking as recorded on the A1 questionnaire & midwife recorded notes.

Similar to alcohol, from this point the research will focus on the ‘smoking at any point in pregnancy’ variable, data from data within the A1 questionnaire, as smoking is not recommended during pregnancy and the literature largely utilises the variable in this form. Binary regression was again utilised to assess potential variables associated with smoking during pregnancy. Again, this does not include outcome variables that will be investigated within Chapters four and five of this thesis. At the univariable level (Table 3.5), maternal age at booking, a highest education level of 'Left before GCSE' compared to 'University', an income of < £18,000, £18-25,000 and 'Do not wish to say' compared to > £43,000 and WIMD score were significantly associated with smoking at any point in pregnancy at $p < .05$. These variables were considered for inclusion in the adjusted multivariable binary regression. All were included after multicollinearity was found not to be present. At the adjusted multivariable level (Table 3.6), χ^2 (10) = 42.15, $p < .001$, only categories within income remained significantly associated with smoking, with an income of < £18,000, £18-25,000 and 'Do not wish to say' compared to > £43,000 greatly increasing the odds of smoking at any point in pregnancy by a factor of 13.36, 12.08 and 12.55 respectively.

Table 3.5 Unadjusted binary regression identifying variables associated with smoking at any point in pregnancy

	p	Exp (B)	95% CI
Fetal sex			
Female	*ref*		
Male	.811	1.09	.53, 2.23
Maternal BMI at booking	.060	1.06	1.00, 1.13
Maternal age at booking	**.044**	.93	.87, 1.00
Parity			
Multiparous	*ref*		
Nulliparous	.388	.70	.31, 1.58
Gestational Diabetes (GDM)			
No	*ref*		
Yes	.616	.59	.08, 4.66
Hypertension			
No	*ref*		
Yes	.298	2.36	.47, 11.84
Highest education level			
Left before GCSE	**<.001**	15.12	4.23, 54.10
GCSE & Vocational	.053	2.98	.99, 9.02
A-level	.073	3.15	.90, 11.05
University	*ref*		
Postgraduate	.173	.22	.03, 1.94
Family income (£)			
<18,000	**<.001**	13.36	3.57, 49.91
18 – 25,000	**<.001**	12.08	3.26, 44.83
25-43,000	.420	1.88	.41, 8.64
>43,000	*ref*		
Do not wish to say	**<.001**	12.55	3.60, 43.78
Conception			
Natural	*ref*		
Assisted	.194	-.12	-.29, .06
Alcohol in pregnancy			
No	*ref*		
Yes	.943	.97	.46, 2.07
Exercise			

	p	Exp (B)	95% CI
No	*ref*		
Yes	.055	.14	.02, 1.04
WIMD score	**<.001**	1.00	1.00, 1.00

Table 3.6 Adjusted binary regression identifying variables associated with smoking at any point in pregnancy

	p	Exp (B)	95% CI
Maternal age at booking	.260	1.05	.96, 1.16
Highest education level			
Left before GCSE	.065	4.80	.91, 25.36
GCSE & Vocational	.620	1.41	.36, 5.50
A-level	.215	2.65	.57, 12.32
University	*ref*		
Postgraduate	.333	.33	.03, 3.15
Family income (£)			
<18,000	**.016**	9.14	1.51, 55.34
18 – 25,000	**.002**	13.96	2.54, 76.76
25-43,000	.431	1.97	.36, 10.72
>43,000	*ref*		
Do not wish to say	**.007**	8.95	1.81, 44.38
WIMD score	.531	1.00	1.00, 1.00

3.3.2.3. Exercise

During pregnancy, 51 (16.60%) participants reported undertaking exercise, whilst 257 (83.40%) refrained from it (Figure 3.5). This was defined as undertaking exercise for at least 30 minutes, at least once a week.

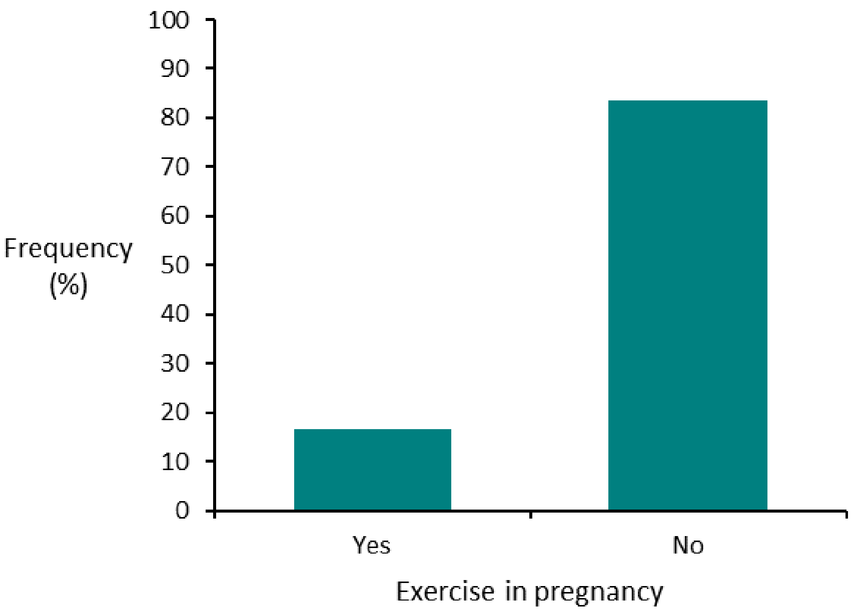


Figure 3.5 Exercise undertaken at any point in pregnancy as recorded on the A1 questionnaire.

To assess the potential variables associated with exercise, binary logistic regression was again utilised. Once again, this does not include outcome variables that will be investigated within Chapters Four and Five of this thesis. At the univariable level (Table 3.7) maternal BMI at booking, a family income of ‘Do not wish to say’ compared to > £43,000, consuming alcohol at any point in pregnancy and WIMD score were significantly associated with exercise. These variables significant at $p < .05$ were considered for inclusion in the adjusted analysis and were all included following confirmation that multicollinearity was not present. In the multivariable adjusted analysis (

Table 3.8), χ^2 (7) = 23.38, p = .001, only maternal BMI at booking remained significantly associated with exercise, with a one unit increase in maternal BMI reducing the odds of undertaking exercise in pregnancy by a factor of .92.

Table 3.7 Unadjusted binary regression identifying variables associated with undertaking exercise in pregnancy

	p	Exp (B)	95% CI
Fetal sex			
Female	*ref*		
Male	.328	.74	.40, 1.36
Maternal BMI at booking	**.010**	.91	.85, .98
Maternal age at booking	.231	1.04	.98, 1.10
Parity			
Multiparous	*ref*		
Nulliparous	.821	.92	.43, 1.95
Gestational Diabetes (GDM)			
No	*ref*		
Yes	.782	.81	.18, 3.72
Hypertension			
No	*ref*		
Yes	.634	1.48	.30, 7.32
Highest education level			
Left before GCSE	.998	.00	.00, .00
GCSE & Vocational	.089	.44	.17, 1.13
A-level	.389	.62	.21, 1.83
University	*ref*		
Postgraduate	.386	1.39	.66, 2.91
Family income (£)			
<18,000	.059	.14	.02, 1.08
18 – 25,000	.179	.42	.12, 1.49
25-43,000	.507	.77	.36, 1.65
>43,000	*ref*		
Do not wish to say	**.040**	.21	.05, .94
Conception			
Natural	*ref*		
Assisted	.103	-.17	-.38, .04
Smoking in pregnancy			
No	*ref*		
Yes	.055	.14	.02, 1.04
Alcohol in pregnancy			
No	*ref*		
Yes	**.045**	1.86	1.01, 3.41
WIMD score	**.028**	1.00	1.00, 1.00

Table 3.8 Adjusted binary regression identifying variables associated with undertaking exercise in pregnancy

	p	Exp (B)	95% CI
Maternal BMI at booking	**.034**	.92	.86, .99
Family income (£)			
<18,000	.166	.22	.03, 1.87
18 – 25,000	.154	.22	.03, 1.77

	p	Exp (B)	95% CI
25-43,000	.507	.76	.34, 1.71
>43,000	*ref*		
Do not wish to say	.051	.13	.02, .99
Alcohol in pregnancy			
No	*ref*		
Yes	.118	1.70	.87, 3.33
WIMD score	.818	1.00	1.00, 1.00

3.3.3. Dietary patterns

This research has been published in Garay et al. (2019). PCA was conducted on data from the 17-item FFQ, with orthogonal varimax rotation applied to aid in the interpretability of the components. The overall Kaiser-Meyer-Olkin value of .73 was greater than the minimum acceptable value of .50 and classified as "Middling" (Hutcheson and Sofroniou, 1999), verifying the sample size adequacy. Bartlett's test of sphericity was statistically significant ($p < .001$), verifying the presence of correlations between the variables. These values confirmed the data were suitable for PCA.

Table 3.9 Eigenvalues & the variance explained by components in the initial exploratory PCA.

Component	Eigenvalues	% variance explained	Cumulative %
1	3.00	17.66	17.66
2	2.14	12.59	30.25
3	1.36	8.02	38.27
4	1.26	7.41	45.68
5	1.08	6.38	52.05
6	.97	5.73	57.78
7	.90	5.30	63.08
8	.83	4.90	67.98
9	.80	4.70	72.68
10	.73	4.32	77.00
11	.70	4.10	81.09
12	.64	3.79	84.88
13	.59	3.49	88.37
14	.57	3.37	91.74
15	.52	3.05	94.79
16	.46	2.73	97.52
17	.42	2.48	100.00

As it is possible to generate as many components as there are variables, an initial exploratory PCA was conducted to obtain eigenvalue data that would allow judgements, both subjective and criterion-based, to be made on the appropriate component solution. Utilising Kaisers criteria that components with eigenvalues greater than one should be retained, because eigenvalues greater than one indicate that the corresponding components explain greater variance than an individual variable, five initial components were identified (Table

3.9). However, inspection of the scree plot (Figure 3.6) indicated that the point of inflection, which is where the curve flattens, was at component three, suggesting that only two components should be retained.

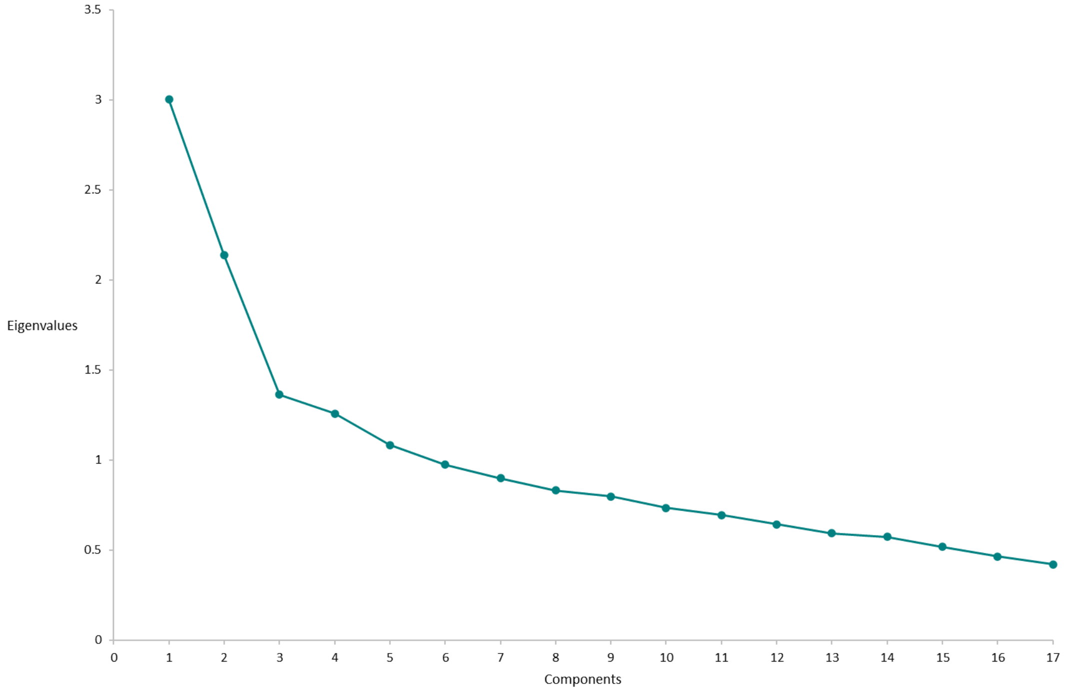


Figure 3.6 Eigenvalues for components in the exploratory PCA

Forced extraction of solutions with five and two components allowed for further examination of the data. Food items with factor loadings of ≥ 0.30 or ≤ -0.30 were considered strongly associated with each component. Values outside of this range were supressed for ease of interpretability. Simplicity and interpretability criterion were utilised to assess the two solutions, with the aim of achieving a meaningful simple structure, with the minimum overlap of loadings between components. As Table 3.10 demonstrates, the five-component solution was not a simple structure and the components were not easily interpretable. However, Table 3.11 highlights that in contrast, the two-component solution has a simple structure with no overlap between components, and the components can be interpreted as meaningful. In light of this and the point of inflection on the scree plot (Figure 3.6), a final solution with two components was determined to be appropriate for this data.

Table 3.10. Factor loadings for each component within the five-component rotated PCA solution

	Component				
	1	2	3	4	5
Salad/veg	.77				
Fruit	.69		-.31		
Fish/shellfish	.60				

	Component				
	1	2	3	4	5
Dried fruit	.60				
Chocolate		.81			
Chips/crisps		.73			
Cakes/biscuits/ice-cream		.65	.30		
Processed meat			.73		
Takeout			.63		
Unprocessed meat	.37		.58		-.31
Soft drinks		.34	.37		
Milk				.73	
Cheese/yoghurt				.63	
Bread/cereals/potatoes/rice/pasta				.40	
Meat alternatives					.70
Supplements					.57
Caffeine				.45	-.47

Table 3.11 Factor loadings for each component within the two-component rotated PCA solution

	Component	
	1	2
Cakes/biscuits/ice-cream	.71	
Chips/crisps	.65	
Processed meat	.54	
Takeout	.54	
Chocolate	.53	
Soft drinks	.43	
Milk	.41	
Unprocessed meat	.41	
Bread/cereals/potatoes/rice/pasta	.40	
Caffeine	.35	
Salad/veg		.76
Dried fruit		.69
Fruit		.60
Supplements		.49
Meat alternatives		.45
Fish/shellfish		.43
Cheese/yoghurt		.41

The two components, or dietary patterns in the final solution (Table 3.11) explained a total 30.25% variance within the data. Dietary pattern one explained 17.66% of variance and was characterised by high factor loadings on and thus high intake of cakes/biscuits/ice-cream, chips/crisps, processed meat, takeout, chocolate, soft drinks, milk, unprocessed meat, bread/cereals/potatoes/rice/pasta and caffeine. Dietary pattern two explained 12.59% of variance and was characterised by high factor loadings on and high intake of salad/vegetables, dried fruit, fruit, supplements, meat alternatives, fish and cheese/yogurt. After consideration of the characteristics and previous dietary pattern literature, dietary patterns one and two were labelled ‘Western’ and ‘Health Conscious’, respectively. Figure 3.7 displays the dietary patterns with factor loadings. Dietary pattern scores for each participant were generated utilising the regression method, which is output that can be selected to be generated by SPSS when conducting a PCA to enable further analysis involving the derived dietary patterns. Scores are typically centred around zero, with greater positive scores indicating higher adherence to a dietary pattern and greater negative scores indicating lower adherence to a dietary pattern.

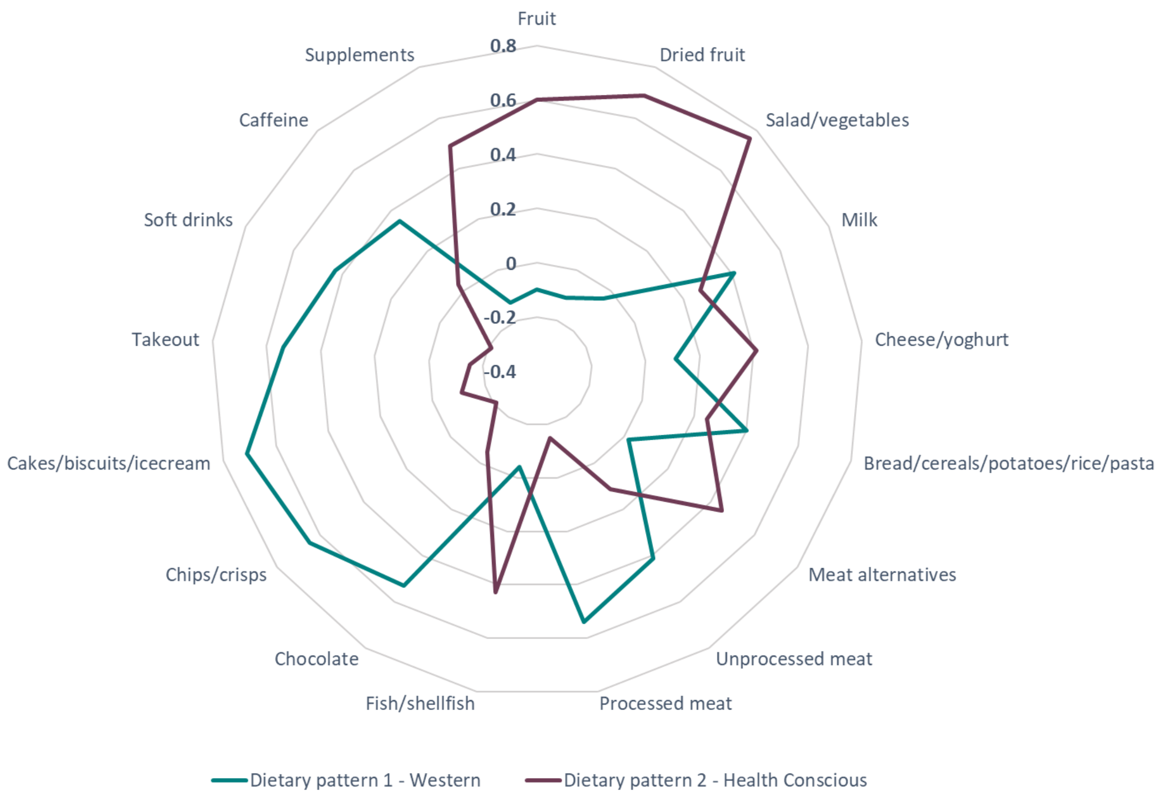


Figure 3.7 Factor loadings for food items in the final two-component PCA solution

Linear regression was utilised to assess variables potentially associated with each dietary pattern. As with previous sections, this does not include outcome variables that will be investigated within Chapters Four and Five of this thesis. At the univariable level (Table 3.12), categories within education and income as well as smoking in pregnancy were significantly positively associated with the Western dietary pattern, whilst maternal age, exercise and WIMD score were significantly negatively associated. Additionally, for the Health Conscious dietary pattern, there were significant positive associations for maternal age, a postgraduate education and WIMD score, whilst maternal BMI, lower education categories, income and smoking in pregnancy were significantly negatively associated.

Table 3.12 Unadjusted linear regression identifying variables associated with dietary patterns during pregnancy

	Western			Health Conscious		
	p	B	95% CI	*p*	B	96% CI
Fetal sex						
Female		*ref*			*ref*	
Male	.837	.02	-.20, .25	.115	.18	-.04, .41
Maternal BMI at booking	.294	.01	-.01, .03	**<.001**	-.04	-.06, -.02
Maternal age at booking	**.012**	-.03	-.05, -.01	**<.001**	.07	.05, .09
Parity						
Multiparous		*ref*			*ref*	
Nulliparous	.276	.16	-.13, .44	.573	-.08	-.36, .20
Gestational Diabetes (GDM)						
No		*ref*			*ref*	
Yes	.691	-.11	-.63, .42	.301	.27	-.25, .79
Highest education level						
Left before GCSE	**.040**	.54	.02, 1.06	**.006**	-.66	-1.14, -.19
GCSE & Vocational	**.026**	.35	.04, .66	**<.001**	-.76	-1.04, -.47
A-level	.617	.10	-.29, .49	**<.001**	-.73	-1.08, -.37
University		*ref*			*ref*	
Postgraduate	.698	-.06	-.37, .25	**.039**	.30	.02, .57
Family income (£)						
<18,000	.451	.16	-.25, .56	**<.001**	-.92	-1.31, -.53
18 – 25,000	.041	.42	.02, .83	**.035**	-.42	-.81, -.03
25-43,000	.892	-.02	-.32, .28	**<.001**	-.61	-.90, -.32
>43,000		*ref*			*ref*	
Do not wish to say	**.001**	.60	.24, .96	**.037**	.37	-.72, -.02
Conception						
Natural		*ref*			*ref*	
Assisted	.903	.04	-.52, .59	.740	.09	-.46, .65
Smoking in pregnancy						
No		*ref*			*ref*	
Yes	**.024**	.43	.06, .80	**.005**	-.53	-.90, -.16
Alcohol in pregnancy						
No		*ref*			*ref*	
Yes	.890	.02	-.22, .26	.905	.01	-.22, .25
Exercise						
No		*ref*			*ref*	
Yes	**.045**	-.31	-.60, -.01	**<.001**	.59	.29, .88
WIMD score	**.003**	$-2.68x10^{-4}$	$-4.44x10^{-4}$, - $9.14x10^{-5}$	**.007**	$2.41x10^{-4}$	$6.54x10^{-5}$, $4.17x10^{-4}$

Variables considered for inclusion in the adjusted multivariable linear regression analysis were all those significant at $p < .05$ at the univariable level. Multicollinearity was assessed via tolerance and VIF scores and found not to be present, allowing all potential variables to be included. At the multivariable level (Table 3.13), no variables remained significantly associated with the Western dietary pattern, $F(13, 253) = 2.46$, $p = .004$. However, at the adjusted level for the Health Conscious dietary pattern, $F(13, 253) = 8.71$, $p < .001$, a one unit increase in maternal BMI at booking was significantly associated with a decrease in Health Conscious dietary pattern score of .03. A highest education level of left before GCSE, GCSE and vocational and A-level compared to a University level education was also significantly associated with a decrease in Health Conscious dietary pattern score of .56, .64 and .55. An income of £25 – 43,000 compared to > £43,000 was associated with a decrease in score of .32. Conversely, a one unit increase in maternal age was associated with an increase of .05 in Health Conscious dietary pattern score. An income of £18 – 25,000 compared to > £43,000 and undertaking exercise were also associated with an increase in Health Conscious dietary pattern score of .39 and .38 respectively.

Table 3.13 Adjusted linear regression identifying variables associated with dietary patterns during pregnancy

	Western			Health Conscious		
	p	B	95% CI	*p*	B	95% CI
Maternal BMI at booking	.540	.01	-.02, .03	**.003**	-.03	-.05, -.01
Maternal age at booking	.055	-.03	-.06, .00	**<.001**	.05	.03, .08
Highest education level						
Left before GCSE	.672	.13	-.48, .74	**.038**	-.56	-1.08, -.03
GCSE & Vocational	.217	.22	-.13, .57	**<.001**	-.64	-.94, -.34
A-level	.763	-.06	-.47, .35	**.002**	-.55	-.90, -.20
University		*ref*			*ref*	
Postgraduate	.821	.04	-.27, .35	.277	.15	-.12, .41
Family income (£)						
<18,000	.092	-.45	-.97, .07	.911	.03	-.42, .47
18 – 25,000	.430	-.21	-.73, .31	.087	.39	-.06, .84
25-43,000	.139	-.24	-.55, .08	**.020**	-.32	-.60, -.05
>43,000		*ref*			*ref*	
Do not wish to say	.132	.34	-.10, .78	.307	.20	-.18, .58
Smoking in pregnancy						
No		*ref*			*ref*	
Yes	.145	.33	-.11, .77	.188	-.26	-.64, .13
Exercise						
No		*ref*			*ref*	
Yes	.227	-.20	-.51, .12	**.007**	.38	.10, .65
WIMD score	.108	-1.72×10^{-4}	-3.82×10^{-4}, 3.80×10^{-5}	.105	-1.50×10^{-4}	-3.31×10^{-4}, 3.30×10^{-4}

3.3.4. Dietary patterns & outcome

This research has been published in Garay et al. (2019). Figure 3.8 displays the CBWC distribution within the cohort. Overall, the median CBWC was 58.60 (IQR = 48.90), with 23 (7.40%) classified as SGA, 245 (78.20%) AGA and 44 (14.10%) LGA.

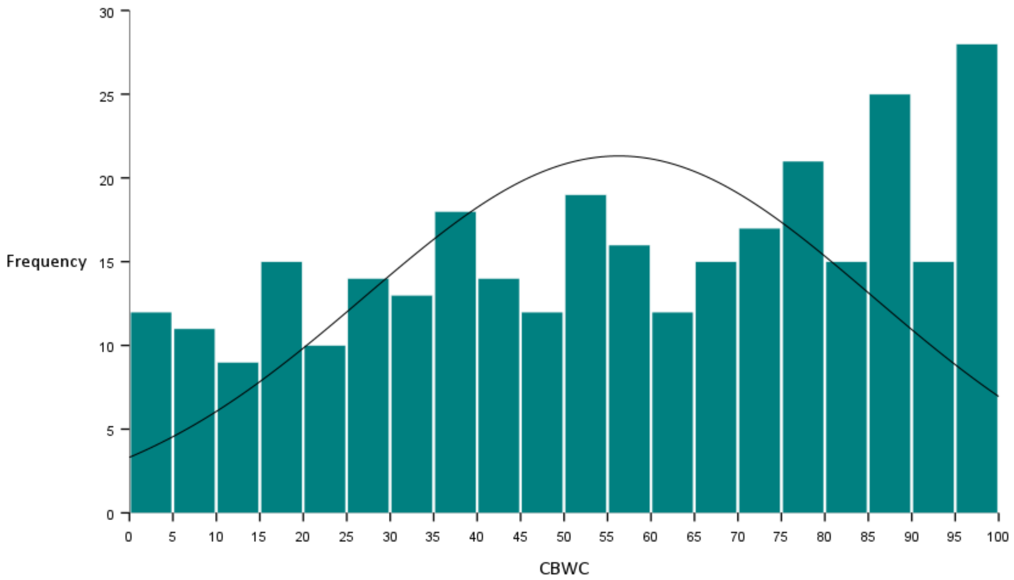


Figure 3.8 The range of custom birthweight centiles present within the GiW cohort

Multivariable linear regression was utilised to assess the association between the dietary patterns, Western and Health Conscious, and overall CBWC (Table 3.14). Only the Health Conscious dietary pattern was significantly associated with overall CBWC prior to adjustment, F(2,300) = 7.54, $p < .001$. This significant association remained following adjustment for the potential confounding variables of maternal age, smoking during pregnancy, alcohol during pregnancy, exercise, GDM, conception and WIMD score, F(9,270) = 4.50, $p < .001$. Specifically, for each one unit increase in Health Conscious dietary pattern score, overall CBWC increased by 4.75.

Table 3.14 Unadjusted & adjusted linear regression assessing the association between dietary patterns & overall CBWC

		p	B	95% CI
Unadjusted	Western	.109	-2.64	-5.87, .59
	Health Conscious	**<.001**	5.81	2.58, 9.04
Adjusted	Western	.297	-1.76	-5.07, 1.55
	Health Conscious	**.010**	4.75	1.17, 8.33

In order to investigate the association between the Western and Health Conscious dietary patterns and SGA compared to AGA births and AGA compared to LGA births, binary regression was utilised (Table 3.15) At the unadjusted level, neither dietary pattern was associated with AGA compared to LGA, $\chi^2(2) = 2.87$, $p = .238$, however a Health Conscious dietary pattern was significantly associated with being born SGA compared AGA $\chi^2(2) = 12.13$, $p = .002$. Due to the lack of significant association for AGA compared to LGA, adjustment was not undertaken. The association between dietary patterns and SGA compared to AGA was adjusted for maternal age, smoking during pregnancy, consuming alcohol during pregnancy, exercise, a GDM diagnosis, method of conception and WIMD score. After adjustment for the potential confounders, $\chi^2(9) = 24.78$, $p = .003$, a Health Conscious dietary pattern remained significantly associated with an SGA compared to AGA birth. Specifically, each one unit increase in dietary pattern score reduced the odds of delivering an SGA compared to an AGA infant by a factor of .45.

Table 3.15 Unadjusted & adjusted binary regression assessing the association between dietary patterns & SGA compared to AGA and AGA compared to LGA

			p	Exp (B)	95% CI
Unadjusted	SGA	Western	.302	1.26	.81,1.97
		Health Conscious	**.003**	.44	.26, .75
	LGA	Western	.694	1.07	.76, 1.52
		Health Conscious	.179	1.28	.89, 1.84
Adjusted	SGA	Western	.850	1.06	.61, 1.84
		Health Conscious	**.013**	.45	.24, .84

3.4. Discussion

Prenatal health behaviours are an important influence on the pregnancy environment. Before the effect of these health behaviours on maternal and infant outcomes can be assessed, it is vital to understand their nature. This chapter aimed to address the first research question of this thesis: What are the health behaviours undertaken in pregnancy by women in Wales? The findings related to this question will now be discussed. It was found that within the GiW cohort, 38.20% of participants consumed alcohol at any point in pregnancy, 11% smoked at any point in pregnancy and only 16.60% undertook exercise. Additionally, two dietary patterns were identified in the population, a Western and a Health Conscious dietary pattern. The factors related to each health behaviour were also explored, whilst the dietary patterns were additionally validated by assessing their association with CBWC.

When focusing on prenatal smoking behaviour, it was found that only 11% of participants reported smoking at any point in pregnancy. This is lower than the most recent data released by the Welsh Government, which indicated that 17% of women reporting smoking in pregnancy in 2020 (Welsh Government, 2021). It is possible that this lower rate is due to the demographics of this cohort, which is generally of higher socioeconomic status and education level, following the trend of the typical nature of cohort studies. However, the potential influence of this should be minimised as there is still a range of demographics, from lowest to highest levels, present within the GiW cohort. Moreover, this figure could also be reflective of the trend that has identified prenatal smoking to be decreasing in general over time (Lange et al., 2018), or the evidence displaying variation in smoking rates between regions. Indeed, whilst the Welsh Government data are reflective of the whole of Wales, the current data reflects the Cardiff health board, which may have contributed to the difference. As such, this research contributes to the understanding of prenatal smoking behaviour in Wales.

Despite guidance recommending particular exercise levels and alcohol cessation in the prenatal period, within the GiW cohort only 16.60% of participants undertook exercise and 38.20% consumed alcohol in pregnancy. Whilst no previous evidence for exercise is available in Wales, these low levels are reflective of other studies conducted in this area. Gjestland et al. (2013) determined that only 14.60% of women achieved the recommended exercise levels in Norway, whilst the only previous study in Wales found similar alcohol consumption levels of 35% (McAndrew et al., 2012). It is important to note that for both prenatal smoking and alcohol consumption, there was a significant difference between what the women reported on their questionnaires and what was recorded on the midwife notes obtained from data within the medical notes. For both behaviours, rates were significantly higher on the self-report questionnaires, perhaps due to participants reluctance to disclose this information to health professionals. This suggests that evidence obtained from data linkage studies and medical notes may be underestimating the prevalence of these behaviours.

This chapter also investigated the factors that influence the identified health behaviours in pregnancy. Whilst many factors were significantly associated with the behaviours at the univariable level, once adjusted fewer variables remained influential. Only income was associated with prenatal alcohol consumption, with an income in the lowest category associated with reduced likelihood of consuming alcohol in pregnancy. This is consistent with studies that have previously identified that higher socioeconomic status or income levels are related to higher levels of alcohol consumption in pregnancy (McCormack et al., 2017). Indeed, it is possible that those with higher incomes are undertaking compensatory healthier behaviours in the mistaken belief that it adjusts for this alcohol intake. Additionally, income was the only factor associated with prenatal smoking behaviour, although in a contrasting direction to that with alcohol. Here, lower income levels were associated with considerably increased likelihood of smoking in pregnancy. However, caution needs to be taken when interpreting these findings as the confidence intervals are extremely high, suggesting a potential issue. Nevertheless, it is reassuring that income, and similar factors such as socioeconomic status, have been associated with smoking outcomes in previous research (Madureira et al., 2020, Kaneko et al., 2008). Regarding exercise, only maternal BMI at booking was associated, with the likelihood of undertaking exercise decreasing as BMI increased. Again, this is supported by previous research, such as that by Baena-García et al. (2021).

As stated above, it was felt that two dietary patterns most accurately reflected the data within the GiW cohort. That is, a Western and a Health Conscious dietary pattern. No factors were found to be associated with the Western dietary pattern in the adjusted analysis. However, factors associated with a decrease in Health Conscious dietary pattern adherence were increasing maternal BMI at booking, lower education levels and a mid-level income. Conversely, increasing maternal age, a lower income level and undertaking exercise were associated with increased adherence to a Health Conscious dietary pattern in pregnancy. This is in line with much of the previous literature in this area, which has identified similar associations. For example, Marvin-Dowle et al. (2018) also found that increasing maternal age was associated with higher adherence to a healthy dietary pattern in a UK population. It is also interesting that undertaking exercise in pregnancy was associated with higher Health Conscious dietary pattern adherence. This supports the evidence previously discussed in Chapter One regarding the co-occurrence and clustering of health behaviours. Indeed, Cucó et al. (2006) also identified a link between exercise and diet. As such, this further emphasises the importance of studying the influence of multiple health behaviours simultaneously. Whilst previous research has identified additional factors associated with the prenatal health behaviours, that were not found in this thesis, this area is rarely investigated in Wales. Thus, these findings are simply representative and informative of this under-researched population and provides improved understanding regarding the nature of health behaviours in Wales.

When comparing these dietary patterns to previous studies, it can be challenging due to the population-specific nature of *a posteriori* patterns that are data driven. These patterns directly and accurately reflect the dietary behaviour of the population of interest. This can be seen in studies conducted in Norway and Finland which identify 'traditional' dietary patterns that are not relevant to other cultures (Arkkola et al., 2008, Englund-Ögge, 2014). However, in general, despite the differences in the naming and specific components of dietary patterns between studies that frequently occur, overall similarities can generally be identified. The

Western dietary pattern within the GiW cohort is similar to the Western dietary pattern derived in a large Australian study (Moran et al., 2017), as well as the Processed and Snack patterns in another UK based study (Flynn, 2016a). Moreover, the Health Conscious dietary pattern here is consistent with Prudent or healthy patterns frequently identified in research (Coathup et al., 2017, Wall et al., 2016), including within the ALSPAC cohort in the UK (Northstone et al., 2007). As such, these dietary patterns provide an accurate reflection of prenatal diet in Welsh populations.

In order to further assess the suitability of the derived dietary patterns, their ability to predict an outcome was assessed, in this case CBWC. In line with previous research, it was identified that the dietary patterns within the GiW cohort do indeed influence birthweight outcomes. Specifically, a Health Conscious dietary pattern was found to increase overall CBWC as well as reduce the risk of delivering an SGA infant. This is similar to previous research that has also identified an association in this area (Thompson et al., 2010, Gete et al., 2020, Biagi et al., 2019). That this association was found supports and validates the dietary patterns that were obtained from the data, both in terms of relevance and that they can be utilised to predict further outcomes. Moreover, as the existing literature rarely utilises CBWC, as discussed in-depth in Chapter One, this finding addresses a gap in the research and improves the current understanding of the influence of dietary patterns on birthweight outcomes. This area will be examined further in Chapter Five, considering the influence of multiple health behaviours simultaneously on a range of birthweight outcomes.

The dietary patterns within the GiW cohort were derived from data collected using an FFQ. This method is advantageous compared to other self-report measures as it provides a longer-term view of dietary behaviour in pregnancy (Thompson et al., 2010). Although concern could be raised that the data were only measured at one timepoint, this potential limitation is minimised as participants were asked to reflect on their dietary intake throughout pregnancy. Moreover, research has indicated that dietary patterns remain relatively stable across pregnancy (Cucó et al., 2006), and thus one timepoint provides accurate representation for the whole prenatal period. It remains possible that the use of self-report FFQ could be open to bias, as perhaps participants would have been reluctant to admit to poor dietary behaviour. Consequently, although FFQ are a frequently utilised measure, ideally the dietary data would have been biologically validated. One way to do this would be to utilise the fatty acid data that was collected within this cohort from both maternal and fetal serum, as maternal fatty acids are reflective of dietary composition. Whilst it was beyond the scope of the thesis, this validation will be undertaken as part of the post-doctoral position that will be undertaken upon the submission of this thesis. Overall, the dietary patterns derived within this cohort provide the foundations of a knowledge base in Wales.

3.5. Conclusion

Health behaviours are an important environmental influence in pregnancy. However the previous evidence available regarding these behaviours in Wales was limited. The prevalence of prenatal alcohol consumption, smoking and exercise were determined and it was identified that two dietary patterns, Western and Health Conscious, were present in this population. The factors influencing these health behaviours were also assessed. As such, this chapter offered insight and greatly improved the existing understanding of the health behaviours undertaken in pregnancy in Wales. Indeed, it is extremely clear that urgent improvement in these prenatal health behaviours is required. Now that the nature of the prenatal health behaviours in the GiW cohort has been determined, it is possible to examine the influence of these behaviours on a range of maternal and infant outcomes.

Chapter 4 - Prenatal health behaviours & maternal outcomes

4.1. Introduction

As discussed in Chapter One, maternal prenatal health behaviours are an environmental influence on pregnancy. These are a particularly important environmental factor due to their modifiable nature which provides scope for improvement. These prenatal health behaviours may have an impact on wide range of outcomes, including those related to the mother. This thesis focuses on the maternally-related areas of gestational weight gain (GWG), maternal mental health and maternal care of the infant relating to breastfeeding and the mother-child relationship. Suboptimal outcomes in these areas are highly prevalent. For example, excessive GWG is estimated to affect 47% of women worldwide (Goldstein et al., 2017), however with the exception of the paper published during this PhD (Garay et al., 2021) no research had investigated this in the UK. Additionally, it is believed that few women worldwide achieve breastfeeding guidelines as outlined by the World Health Organisation (WHO) (Victora et al., 2016).

These outcomes are not only important in themselves, but all are also related to further future health and developmental outcomes for mother and child. For example, suboptimal prenatal mental health outcomes can severely impact the postnatal mental health of the mother (Grigoriadis et al., 2019), whilst also increasing the risk of being born low birthweight and neurocognitive delays in childhood (Grigoriadis et al., 2018). As such, exploring how maternal health behaviours in pregnancy influence maternal outcomes could lead to the knowledge that would enable improvements in the lifelong health of both mother and child.

The focus of the previous chapter was to establish the maternal health behaviours that are present within the Grown in Wales (GiW) cohort. Now this has been determined it is possible to examine the association between these health behaviours and the highlighted maternal outcomes. Chapter One provided an overview of the existing research in this area. In summary, the evidence appears mixed and inconsistent. Prenatal smoking is the health behaviour that is most heavily focused on in the literature in general, with less interest on dietary patterns, alcohol or exercise. Perhaps as a consequence of this, smoking is most consistently related to the outcomes of breastfeeding and maternal mental health, whereas the literature on the influence of other health behaviours is more likely to be contradictory. Regarding GWG, there is contradictory research on the influence of all health behaviours of interest. For maternal mental health, smoking is generally accepted to influence depression and anxiety symptoms, whilst prenatal alcohol consumption, exercise and dietary pattern evidence is highly inconsistent. Although, regarding dietary patterns there appears to be a trend towards positive outcomes associated with healthier dietary patterns and mental health. In relation to breastfeeding, smoking is consistently influential however there is a paucity of literature on other health behaviours. The influence of prenatal health behaviours on the mother-child relationship has barely been addressed. Finally, generally research has neglected to investigate any of these areas in Wales.

This thesis seeks to address the gaps in this literature and provide further insight into the areas full of inconsistencies. Chapter Four begins to address the second research question: What is the influence of the maternal health behaviours in pregnancy on maternal and infant outcomes. We will explore the hypotheses outlined in Chapter One that 1) Healthy maternal health behaviours in pregnancy are associated with positive maternal and infant outcomes 2) Unhealthy maternal health behaviours in pregnancy are associated with negative or suboptimal maternal and infant outcomes. To address this, Aim two of the thesis will be utilised.

Aim 2. To determine the influence of maternal health behaviours in pregnancy on short and longer term maternal outcomes.

- To establish the association between maternal prenatal health behaviours and gestational weight gain.
- To determine the association between maternal prenatal health behaviours and perinatal maternal mental health, in the form of depression & anxiety symptoms.
- To investigate the association between maternal prenatal health behaviours and maternal care in the form of breast feeding & the mother-infant/child relationship.

4.2. Method

4.2.1. Participants

Excluding the seven participants who withdrew from the cohort, 348 were initially eligible for inclusion. As with Chapter Three, eligibility criteria for all analyses required a Caucasian ethnicity, to maintain the homogeneity of the sample (Bornstein et al., 2013), and for the infants gestational age to be $\geq$ 37 weeks. Analyses that utilised data from the Y1 questionnaire required the infant to be of <18 months of age. Additionally, analyses utilising Y1 and Y4 data required the infants to have no diagnosed developmental or serious health conditions. In light of this criteria, overall 312 participants were eligible for the A1 analyses, 116 for the Y1 analyses and 131 for the Y4 analyses. However, as with the previous chapter, due to slight variation in the availability of data and to ensure clarity, the specific participant numbers involved in each analysis are outlined at the start of each results subsection.

4.2.2. Materials

The materials have been outlined in depth in Chapter Two. Data on the health behaviours of alcohol consumption, smoking and exercise in pregnancy (categorical: Yes/No) were extracted from the A1 questionnaire. As outlined in previous chapters, in line with existing research the alcohol and smoking variables for trimester one and trimesters two and three were combined into the categorical variables “alcohol at any point in pregnancy” and “smoking at any point in pregnancy” with responses of ‘yes’ or ‘no’. These were the only alcohol and smoking variables utilised for the analyses within this chapter. Dietary patterns (continuous) were generated from the 17-item food frequency questionnaire (FFQ) within the A1 questionnaire, with the process of deriving the Western and Health Conscious dietary patterns and scores outlined in Chapter Three.

The A1 questionnaire also incorporated data from the Edinburgh Postnatal Depression Scale (EPDS) and State-Trait Anxiety Inventory (STAI), utilised to assess maternal mental health symptoms. These measures have been outlined in detail in Chapter Two. Briefly, the EPDS has a maximum total score of 30, with scores ≥ 13 indicative of probable depression. The trait subscale of the STAI has a maximum total score of 80, with scores of ≥ 40 indicative of probable anxiety. Both the total scores (continuous) and thresholds for clinical significance (categorical: Above threshold/Below threshold) for the EPDS and STAI were utilised in the analyses.

Data from the A1 questionnaire and the midwife recorded notes enabled GWG (continuous and categorical) to be calculated for participants. This required the participants pre-pregnancy weight (continuous) as recorded on the A1 questionnaire and the weight at delivery (continuous) as recorded on the midwife notes. The participants pre-pregnancy body mass index (BMI) (continuous and categorical: Underweight/Healthy/Overweight/Obese) was also calculated from the height (continuous) recorded on midwife notes, to enable assessment of GWG classifications. GWG categories were classified according to the Institute of Medicine (IOM) 2009 guidelines (Institute of Medicine, 2009) (Table 4.1). Participants who gained below the recommendation were classified as ‘Inadequate GWG’, within the recommendation as ‘Normal GWG’ and above recommendation as ‘Excessive GWG’. Seven participants were identified as having lost weight in pregnancy. On the advice gained through peer review, these participants were incorporated into the inadequate GWG category. It was not possible to assess associations of health behaviours with GWG when stratified by BMI as participant numbers became too low, instead only descriptive statistics were possible. Instead, the association was assessed through overall total GWG and GWG classifications.

Table 4.1 Institute of Medicine guidelines for gestational weight gain categorised by pre-pregnancy BMI.

BMI	Recommended weight gain (kg)
Underweight (< 18.5)	15.5 - 18
Healthy (18.5 - 24.9)	11.5 - 16
Overweight (25 - 29.9)	7 - 11.5
Obese (> 30)	5 - 9

Data on breastfeeding was available from both the Y1 and Y4 questionnaires. The breastfeeding initiation variables in each questionnaire were combined to form a single breastfeeding variable “breastfed infant”, which was categorised as ‘yes’ or ‘no’. The breastfeeding variables regarding breastfeeding duration were also combined into the variable “breastfeeding for duration of guidelines”, again categorised as ‘yes’ or ‘no’. The Y1 questionnaire also included the Postpartum Bonding Questionnaire (PBQ) (Brockington et al., 2001), which assessed maternal-infant bonding. Scores were available for both the total PBQ as well as for the three individual factors (continuous). Although it is possible to utilise both total scores and thresholds indicating high risk categories, the thresholds (categorical) were only utilised briefly for descriptive data, as the participant numbers within the high-risk categories were minimal. Finally, data on the mother-infant/child relationship was also available from the Y4 questionnaire which incorporated the Child-Parent Relationship Scale (CPRS) (Pianta, 1992). The CPRS was developed to assess parent perceptions of their relationship with their child, with scores available for three domains (continuous). Both the PBQ and CPRS are outlined in Chapter Two.

The potentially confounding variables that were included in the different adjusted analyses for each outcome were selected on the basis that the literature review identified them as influential for that outcome, previous papers from the GiW cohort found them to be influential or on the advice obtained through peer review. As such, the confounding variables included in the adjusted models were different for each outcome analysis. For the adjusted GWG analysis these confounders included overall EPDS score (continuous), maternal BMI at booking (categorical: Underweight/Healthy/Overweight/Obese) and income (categorical:

£25,000 or above/Below £25,000). These were selected as they were found to be influential in Garay et al. (2021). For the adjusted perinatal mental health analysis these included Welsh Index of Multiple Deprivation (WIMD) score (continuous), education (categorical: University or above/Below University), income (categorical: £25,000 or above/Below £25,000), parity (categorical: Nulliparous/Multiparous), fetal sex (categorical: Male/Female) and mental health history (categorical: Yes/No). For Breastfeeding, the confounders in the adjusted analysis were BMI at booking (continuous), maternal age (continuous), education (categorical: University or above/Below University), WIMD score and mode of delivery (Categorical: Elective caesarean section (ELCS)/Emergency caesarean section (CS)/Spontaneous vaginal delivery/Instrumental). For adjusted analyses of the mother infant/child relationship the confounders selected were overall EPDS score (continuous), maternal age (continuous), education (categorical: University or above/Below University) and parity (categorical: Nulliparous/Multiparous). These variables were all outlined in Chapter Two and were obtained from either the A1 questionnaire or the midwife recorded notes.

4.2.3. Statistical analysis

Normality of variables was investigated through consideration of histograms, skewness, kurtosis, Kolmogorov-Smirnov and Shapiro-Wilk values. Descriptive statistics for outcome variables were determined by the assessment of normality. Linear and binary multivariable regression analyses were undertaken as relevant to assess the associations between health behaviours and the various outcomes assessed in this chapter. The unadjusted and adjusted models here utilise method two as outlined in section 2.1.6. Model assumptions as outlined in Chapter Two were assessed and found to not be violated. All analyses were undertaken initially at the unadjusted multivariable level. Those analyses significant at the unadjusted level were adjusted for potential confounders identified from the literature. In the case of GWG and perinatal mental health this included risk factors identified in previously published GiW research (Garay et al., 2021, Janssen et al., 2018). Adjustment took place once multicollinearity was confirmed to not be present through the use of correlation coefficients or VIF and tolerance scores where appropriate. Here, the independent variables were the five health behaviours (unadjusted model) and the five health behaviours and confounding variables (adjusted model), whilst the dependent variables were the maternal outcomes of interest.

4.3. Results

4.3.1. Gestational weight gain

This analysis section has been adapted from the paper Garay et al. (2021) produced during this PhD, which focused on biopsychosocial predictors of GWG. 260 participants were included in this analysis of overall GWG data. The median overall GWG was identified as 14.85 kg (IQR = 7.98) with a range of 88.24 kg. Data on GWG categories was available for 254 participants, due to six participants having missing data on pre-pregnancy BMI. Of these 254 participants, 38 (15%) were classified as inadequate GWG, 77 (30.30%) as normal GWG and 139 (54.70%) as excessive GWG (Figure 4.1).

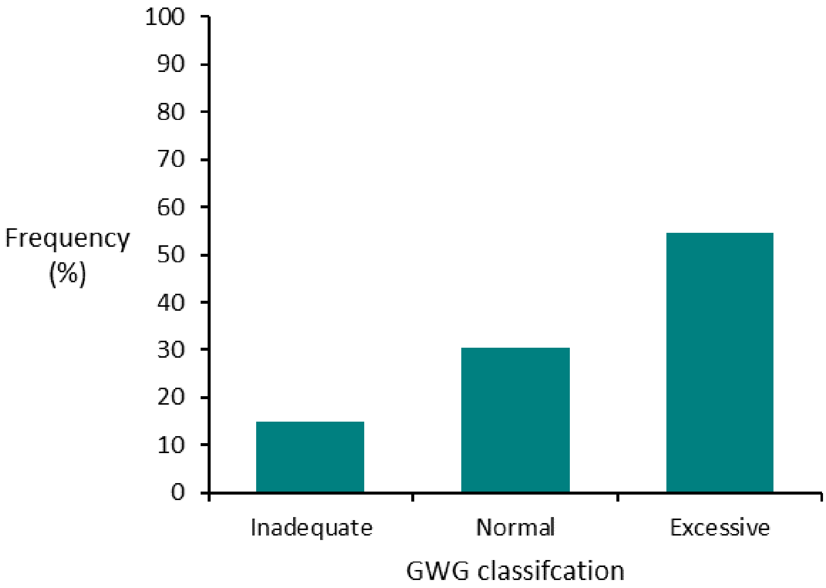


Figure 4.1 The frequency of participants within each Institute of Medicine specified gestational weight gain category

The frequency of participants within each GWG classification when stratified by pre-pregnancy BMI are displayed in Figure 4.2. The median GWG within the underweight pre-pregnancy BMI category was 17.85 kg (IQR = 23.37, range = 60.60 kg, low GWG N = 2, normal GWG N = 1, excessive GWG N = 3), the healthy pre-pregnancy BMI was 15.21 kg (IQR = 7.10, range = 59.71 kg, low GWG N = 22, normal GWG N = 55, excessive GWG N = 55), the overweight category was 15.92 kg (IQR = 7.40, range=27.40 kg, low GWG N = 3, normal GWG N = 16, excessive GWG N = 59) and the obese category was 10.61 kg (IQR = 10.63, range = 53.04 kg, low GWG N = 11, normal GWG N = 5, excessive GWG N = 22).

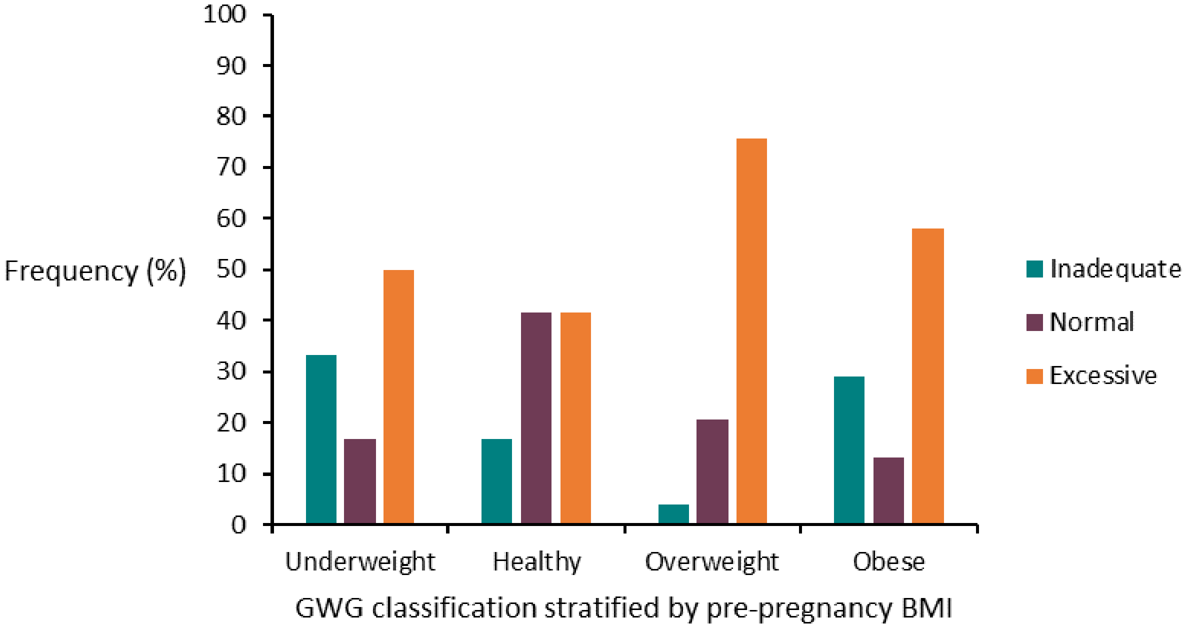


Figure 4.2 The frequency of participants within each Institute of Medicine specified gestational weight gain classification, stratified by pre-pregnancy body mass index.

It was not possible to explore the association between health behaviours and inadequate GWG or GWG stratified by pre-pregnancy BMI category due to the low participant numbers within these groups. Multivariable linear regression was utilised to explore the association between health behaviours and overall GWG (Table 4.2). Unadjusted regression, F(5,240) = 1.72, p < .049, identified that alcohol at any point in pregnancy was significantly negatively associated with overall GWG. This association was adjusted for potential confounding variables; overall A1 EPDS score, maternal BMI at booking and income (above/below £25,000). Multicollinearity was found not to be present and the adjusted analysis, F(8,200) = .719, p = .674, identified that no health behaviours remained significantly associated with overall GWG.

Table 4.2 Unadjusted & adjusted linear regression identifying associations between prenatal health behaviours & overall GWG.

		p	B	95% CI
Unadjusted	Smoking	.107	-2.71	-6.00, .59
	Alcohol	**.045**	-2.02	-4.00, -.04
	Exercise	.363	-1.23	-3.88, 1.43
	Western	.363	.44	-.51, 1.40
	Health Conscious	.341	.49	-.52, 1.49
Adjusted	Smoking	.605	-1.10	-5.26, 3.07
	Alcohol	.088	-1.91	-4.11, .29
	Exercise	.742	.47	-2.34, 3.27
	Western	.523	.34	-.72, 1.41
	Health Conscious	.585	.31	-.82, 1.44

Multivariable binary regression was employed to explore the association between health behaviours and excessive compared to normal GWG (Table 4.3). At the unadjusted level, χ^2 (5) = 8.91, p = .035, alcohol at any point in pregnancy was significantly negatively associated with excessive compared to normal GWG. This association was adjusted for the same potential confounders outlined previously; overall A1 EPDS score, maternal BMI at booking and income (above/below £25,000). After confirming multicollinearity was not present, the adjusted analysis, χ^2 (8) = 31.75, p < .001, identified that consuming alcohol at any point in pregnancy remained significantly associated with excessive compared to normal gestational weight gain. Specifically, consuming alcohol was associated with increased odds of excessive compared to normal gestational weight gain by a factor of 2.22.

Table 4.3 Unadjusted & adjusted binary regression identifying associations between prenatal health behaviours & excessive compared to normal GWG

		p	Exp (B)	95% CI
Unadjusted	Smoking	.266	.57	.22, 1.53
	Alcohol	**.027**	.50	.28, .93
	Exercise	.253	1.58	.72, 3.48
	Western	.283	1.18	.87, 1.61
	Health Conscious	.673	1.07	.78, 1.46
Adjusted	Smoking	.151	2.69	.70, 10.38
	Alcohol	**.030**	2.22	1.08, 4.56
	Exercise	.398	1.46	.61, 3.48
	Western	.403	1.17	.81, 1.69
	Health Conscious	.224	1.25	.87, 1.81

4.3.2. Perinatal mental health

4.3.2.1. Depression

Data on prenatal depression symptoms using the EPDS was available for 307 participants. The median overall EPDS score was 7.00 (IQR = 6.00), with the distribution of scores displayed in Figure 4.3. When considered classifications, 264 (84.60%) participants obtained a score of ≤ 12 and 43 (13.80%) obtaining a score of ≥ 13, indicative of probable depression (Figure 4.4).

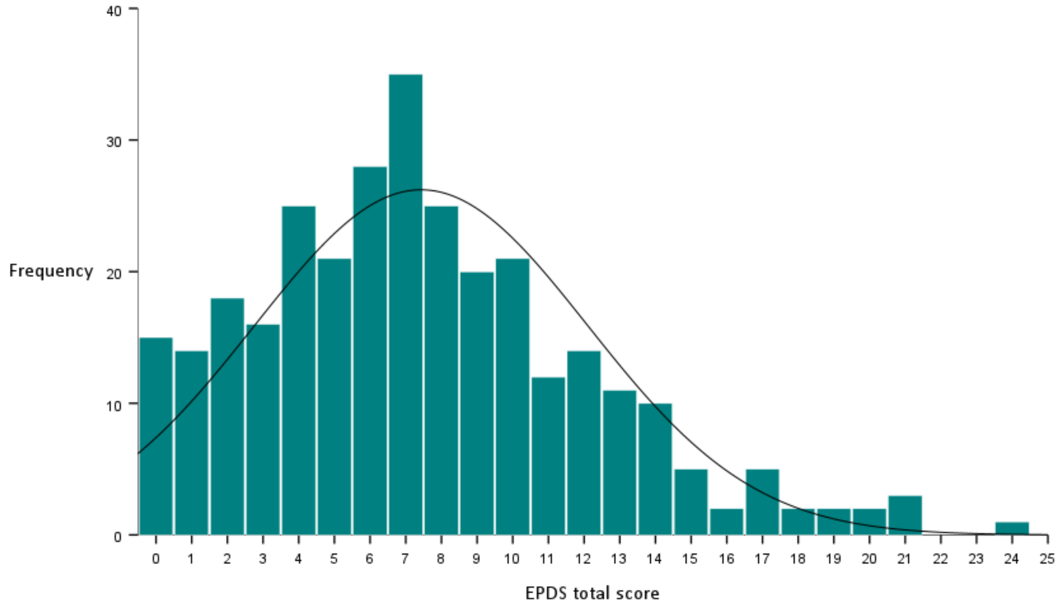


Figure 4.3 The distribution of total Edinburgh Postnatal Depression Scale scores at the A1 timepoint

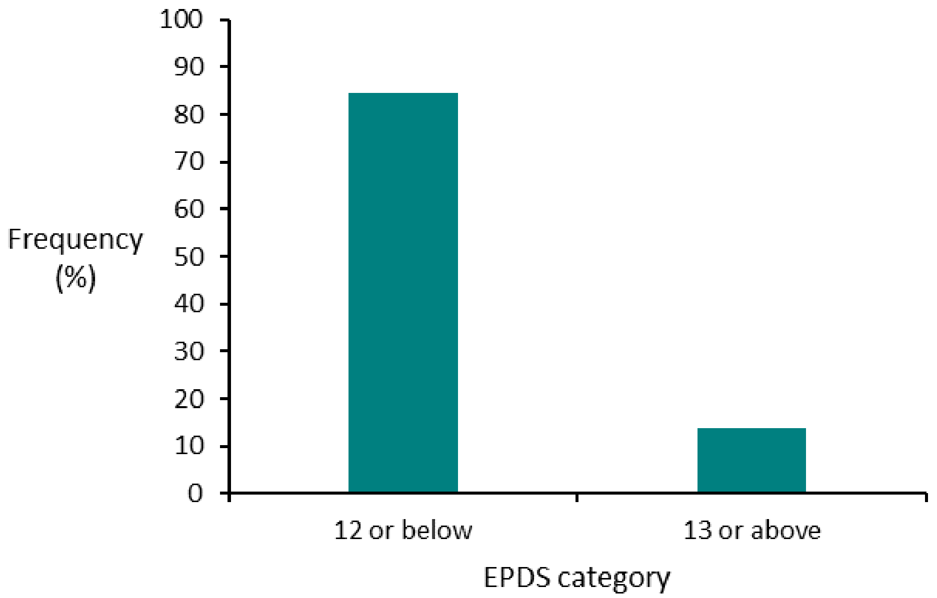


Figure 4.4 The frequency of participants obtaining Edinburgh Postnatal Depression Scale scores above & below the threshold for clinical significance at the A1 timepoint

Linear regression was utilised to investigate the relationship between health behaviours and total EPDS scores (Table 4.4). The unadjusted multivariable analysis, F(5,285) = 3.91, *p* = .002, revealed that both smoking in pregnancy and a Western dietary pattern were significantly positively associated with total EPDS scores. This analysis was adjusted for the potential confounders of WIMD score, education (above/below university level), income (above/below £25,000), parity, fetal sex and mental health history. After confirming multicollinearity was not present, the adjusted multivariable analysis, F(11,231) =

4.59, $p < .001$, identified that no health behaviours remained significantly associated with total EPDS score.

Table 4.4 Unadjusted & adjusted linear regression identifying associations between maternal health behaviours in pregnancy and total EPDS scores.

		p	B	95% CI
Unadjusted	Smoking	**.002**	2.85	1.02, 4.68
	Alcohol	.383	.49	-.62, 1.61
	Exercise	.678	.31	-1.17, 1.79
	Western	**.028**	.611	.07, 1.15
	Health Conscious	.313	-.29	-.85, .27
Adjusted	Smoking	.757	.36	-1.95, 2.67
	Alcohol	.104	.97	-.20, 2.15
	Exercise	.746	.24	-1.23, 1.71
	Western	.132	.44	-.13, 1.01
	Health Conscious	.288	.29	-.95, .28

Binary regression was employed to consider the relationship between health behaviours and EPDS scores ≥ 13 compared to ≤ 12 (Table 4.5). The unadjusted multivariable analysis, χ^2 (5) = 17.35, $p = .004$, identified that smoking at any point in pregnancy and a Western dietary pattern were positively associated with EPDS scores ≥ 13. This analysis was adjusted for the same potential confounders as outlined above. Multicollinearity was not present and the adjusted multivariable binary regression analysis, χ^2 (11) = 42.84, $p < .001$, identified that only a Western dietary pattern remained significantly associated with EPDS score. A one unit increase in Western dietary pattern score increased the odds of an EPDS score ≥ 13 compared to ≤ 12 by a factor of 1.90.

Table 4.5 Unadjusted & adjusted multivariable binary regression examining the association between health behaviours & EPDS scores above compared to below the threshold for clinical significance.

		p	Exp (B)	95% CI
Unadjusted	Smoking	**.048**	2.55	1.01, 6.43
	Alcohol	.484	1.28	.65, 2.53
	Exercise	.149	1.92	.79, 4.62
	Western	**.002**	1.72	1.21, 2.44
	Health Conscious	.504	.88	.62, 1.27
Adjusted	Smoking	.407	1.88	.42, 8.35
	Alcohol	.200	.54	.21, 1.38
	Exercise	.273	.53	.17, 1.64
	Western	**.007**	1.90	1.19, 3.02
	Health Conscious	.727	.92	.57, 1.49

4.3.2.2. Anxiety

Data on prenatal anxiety symptoms using the STAI was available for 303 participants. The median total STAI score was 34.00 (IQR = 12.00), with the distribution of scores displayed in Figure 4.5. Regarding classifications, 219 (72.30%) participants reported a score of ≤ 39 and 84 (27.70%) a score of ≥ 40, indicative of probable anxiety (Figure 4.6).

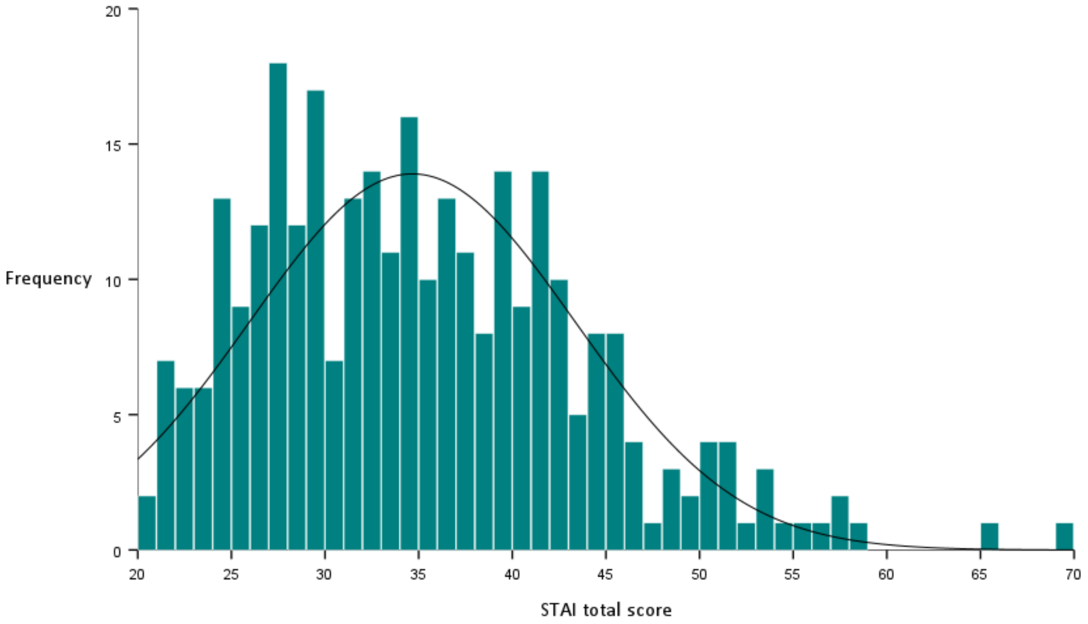


Figure 4.5 The distribution of total State-Trait Anxiety Inventory scores at the A1 timepoint

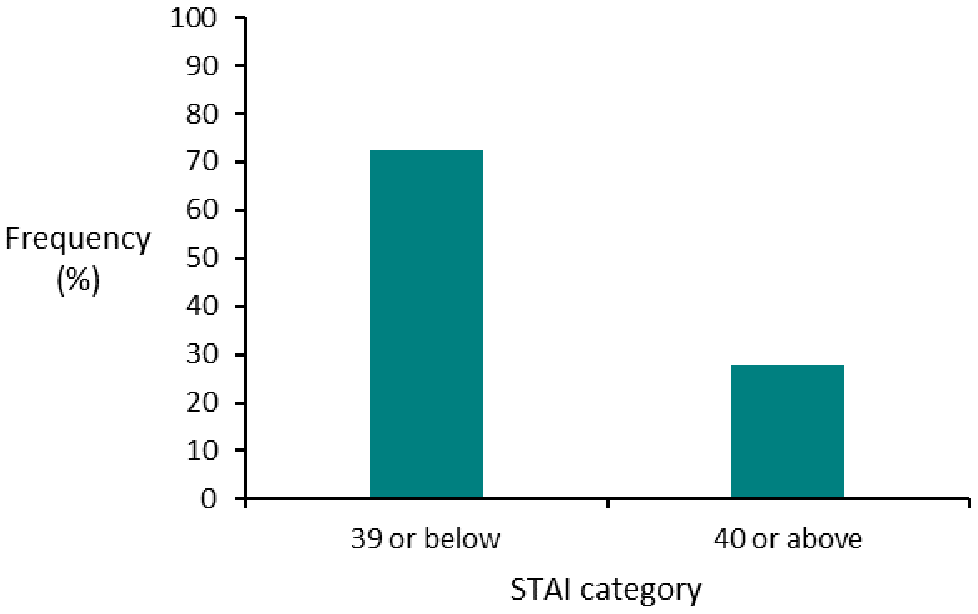


Figure 4.6 The frequency of participants obtaining State-Trait Anxiety Inventory scores above & below the threshold for clinical significance at the A1 timepoint

Linear regression was utilised to investigate the relationship between prenatal health behaviours and total STAI scores (Table 4.6). At the unadjusted multivariable level, $F(5,281) = 2.51$, $p = .030$, only smoking was significantly positively associated with total STAI scores. This analysis was adjusted for the same potential confounders as that utilised previously in the EPDS analyses; WIMD score, education (above/below university level), income (above/below £25,000), parity, fetal sex and mental health history. After confirming no multicollinearity was present, the adjusted multivariable linear regression, $F(11,229) = 4.34$, $p < .001$, identified that no health behaviours remained significantly associated with total STAI scores.

Table 4.6 Unadjusted & adjusted multivariable linear regression identifying the association between prenatal health behaviours & total STAI scores

		p	B	95% CI
Unadjusted	Smoking	**.011**	4.44	1.03, 7.85
	Alcohol	.582	.58	-1.50, 2.67
	Exercise	.862	-.24	-3.00, 2.51
	Western	.061	.97	-.05, 1.99
	Health Conscious	.841	.11	-.94, 1.16
Adjusted	Smoking	.947	-.15	-4.45, 4.17
	Alcohol	.219	1.37	-.83, 3.57
	Exercise	.775	.40	-2.34, 3.14
	Western	.210	.68	-.39, 1.75
	Health Conscious	.977	.02	-1.13, 1.17

Additionally, binary regression was undertaken to analyse the association between health behaviours and STAI scores ≥ 40 compared to ≤ 39 (Table 4.7). Unadjusted multivariable binary regression, $\chi^2(5) = 6.17$, $p = .290$, identified no significant associations between health behaviours and STAI scores ≥ 40. As such, no further adjustment analysis was required.

Table 4.7 Unadjusted multivariable binary regression identifying the association between health behaviours & STAI scores above compared to below the threshold for clinical significance

	p	Exp(B)	95% CI
Smoking	.153	1.81	.80, 4.09
Alcohol	.237	1.38	.81, 2.36
Exercise	.763	.89	.43, 1.87
Western	.271	1.16	.89, 1.52
Health Conscious	.537	.92	.70, 1.21

4.3.3. Maternal care

4.3.3.1. Breastfeeding

Data were available for 149 participants on the initiation of breastfeeding and for 107 participants on the duration of breastfeeding. A total of 43 (28.90%) participants reported not breastfeeding whilst 106 (71.10%) breastfed their infant (Figure 4.7). Of those that reported breastfeeding, when considering breastfeeding duration 35 participants (32.70%) did not meet the recommendations and 72 (67.30%) met the recommendations to breastfeed for six months (Figure 4.7).

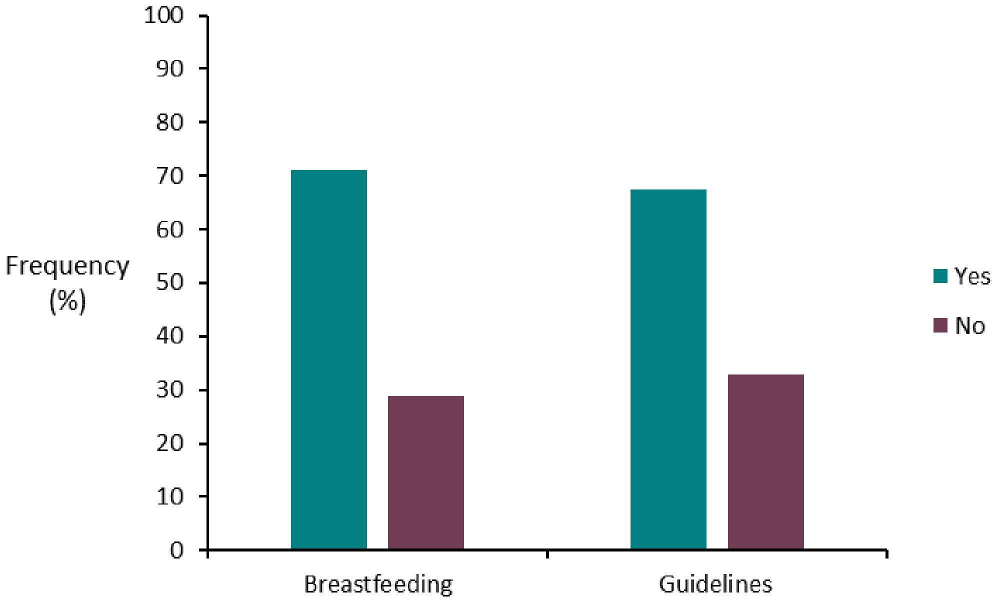


Figure 4.7 The frequency of participants breastfeeding and of those meeting the World Health Organisation breastfeeding duration guidance

Multivariable binary regression was utilised to investigate the association between prenatal health behaviours and breastfeeding initiation (Table 4.8). At the unadjusted level, χ^2 (5) = 15.00, p = .010, the Health Conscious dietary pattern was significantly positively associated with breastfeeding initiation. This analysis was adjusted for the potential confounders; BMI at booking, maternal age at booking, education (above/below university level), WIMD score and if mode of delivery was an ELCS. After confirming multicollinearity was not present, at the adjusted level, χ^2 (10) = 27.96, p = .002, a Health Conscious dietary pattern remained significantly associated with breastfeeding initiation. A one unit increase in Health Conscious dietary pattern score increased the odds of breastfeeding initiation compared to not breastfeeding by a factor of 1.70.

Table 4.8 Unadjusted and adjusted multivariable binary regression assessing the association between maternal health behaviours in pregnancy & breastfeeding initiation.

		p	Exp(B)	95% CI
Unadjusted	Smoking	.971	1.03	.20, 5.27
	Alcohol	.562	.80	.38, 1.72
	Exercise	.760	.85	.31, 2.38
	Western	.070	.66	.42, 1.03
	Health conscious	**.003**	2.01	1.27, 3.18
Adjusted	Smoking	.660	.66	.10, 4.28
	Alcohol	.135	1.92	.82, 4.53
	Exercise	.777	1.18	.38, 3.61
	Western	.417	.81	.50, 1.34
	Health conscious	**.038**	1.70	1.03, 2.81

Multivariable binary regression was also used to consider the association between maternal health behaviours in pregnancy and if the breastfeeding duration met the recommendations to breastfeed for six months (Table 4.9). The univariable analysis, χ^2 (5) = 6.49, *p* = .261, identified that the Health Conscious dietary pattern was significantly positively associated with breastfeeding duration. Following adjustment for the same potential confounders outlined above and identifying that multicollinearity was not present, no health behaviours remained significantly associated with breastfeeding duration, χ^2 (10) = 13.12, *p* = .271.

Table 4.9 Unadjusted & adjusted multivariable analysis assessing the association between prenatal health behaviours & breastfeeding for the recommended duration of six months compared to a shorter duration.

		p	Exp(B)	95% CI
Unadjusted	Smoking	.399	2.94	.24, 36.98
	Alcohol	.798	1.12	.46, 2.73
	Exercise	.497	1.49	.47, 4.73
	Western	.911	1.03	.62, 1.71
	Health Conscious	**.029**	1.74	1.06, 2.86
Adjusted	Smoking	.444	.36	.03, 4.89
	Alcohol	.824	.90	.34, 2.35
	Exercise	.922	.94	.28, 3.19
	Western	.665	1.14	.64, 2.01
	Health Conscious	.086	1.60	.94, 2.75

4.3.3.2. Mother-infant/child relationship

4.3.3.2.1. Mother-infant relationship

Data from 117 participants was eligible for inclusion in this analysis. The median total score of the overall PBQ was 7.00 (IQR = 8.00), with the distribution of scores displayed in Figure 4.8. Regarding the specific factors, the median score on factor one was 4.00 (IQR =

5.25), factor two was 1.00 (IQR = 2.00) and on factor three was 2.00 (IQR= 3.00) (Figure 4.9). When separated into the high-risk categories, two participants had a score in the high-risk category for the overall PBQ score, five participants were in the high-risk category for factor one, whilst no participants had scores in the high-risk categories for factors two and three. Due to these low numbers, no further analysis was undertaken utilising the risk categories for each factor. Instead, the analysis focused on total PBQ scores for each factor.

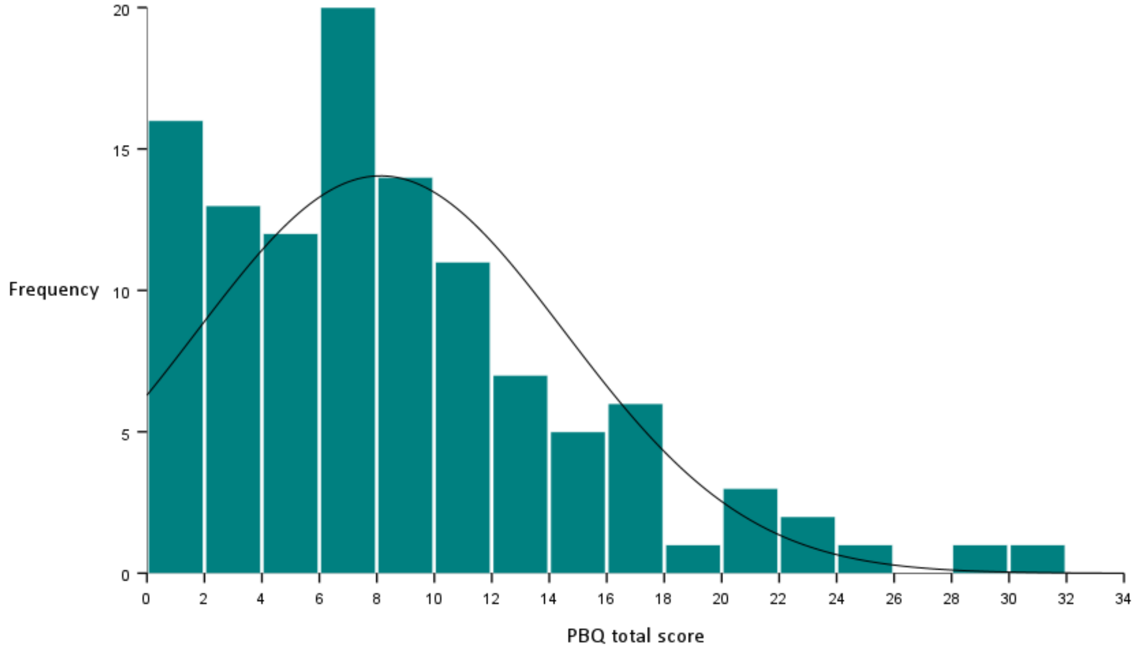
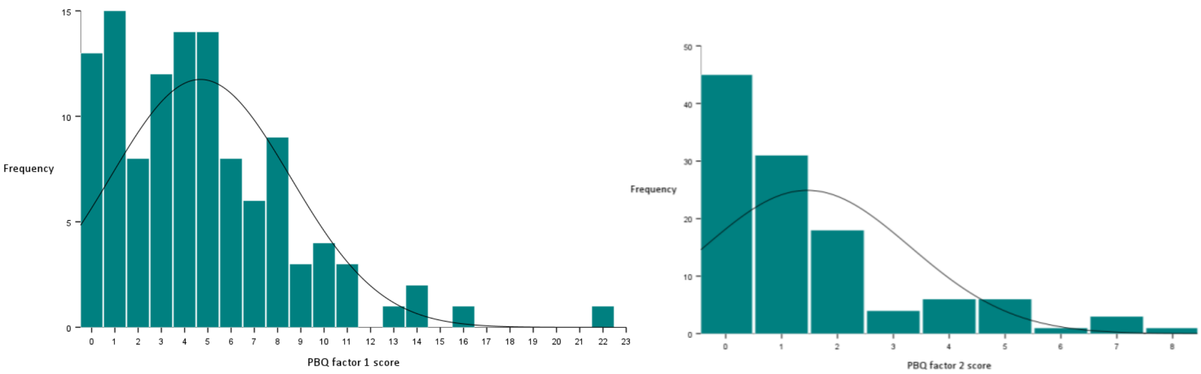


Figure 4.8 The distribution of total overall Postpartum Bonding Questionnaire scores



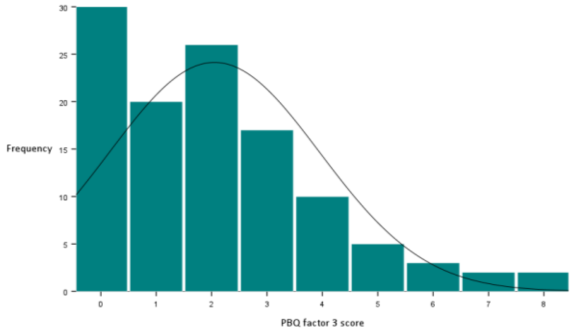


Figure 4.9 The distribution of scores on each factor of the Postpartum Bonding Questionnaire

Linear regression was utilised to consider the association between health behaviours and total PBQ score (Table 4.10). The unadjusted multivariable analysis, F(5,106) = 2.41, *p* = .041, identified that only a Health Conscious dietary pattern was significantly associated with total PBQ score. This analysis was adjusted for the potential confounders of total A1 EPDS score, maternal age at booking, education (above/below university level) & parity. After adjustment and ensuring that multicollinearity was not present, F(9,98) = 2.14, *p* = .033, it was identified that a Health Conscious dietary pattern was no longer significantly associated with total PBQ. However, undertaking exercise in pregnancy was now significantly associated with a decrease in total PBQ score of 3.18.

Table 4.10 Unadjusted & adjusted multivariable linear regression addressing the association between prenatal health behaviours & total PBQ score

		p	B	95% CI
Unadjusted	Smoking	.332	2.61	-2.70, 7.93
	Alcohol	.297	1.26	-1.12, 3.64
	Exercise	.056	2.91	-.08, 5.89
	Western	.307	-.71	-2.09, .66
	Health conscious	**.049**	-1.34	-2.67, -.01
Adjusted	Smoking	.839	.58	-5.07, 6.23
	Alcohol	.369	1.13	-1.35, 3.61
	Exercise	**.043**	-3.18	-6.27, -.10
	Western	.321	-.73	-2.18, .72
	Health conscious	.067	-1.40	-2.89, .10

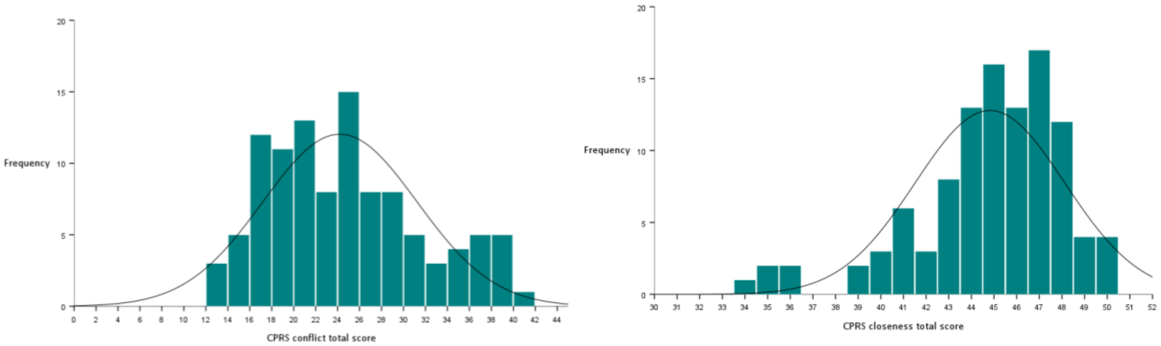
Linear regression was also used to investigate the relationship between health behaviours and the three factors on the PBQ (Table 4.11). At the unadjusted level, factor one F(5,107) = 2.57, *p* = .031, factor two , F(5,108) = 1.73, *p* = .135, factor three , F(5,108) = .969, *p* = .440, the only significant finding was the positive association between undertaking exercise in pregnancy and factor one on the PBQ. As such, only the factor one analysis was further adjusted for the same potential confounders as outlined above; prenatal depression symptoms, maternal age at booking, education (above/below university level) and parity. After adjustment for potential confounders and ensuring no multicollinearity, the association remained significant, F(9,99) = 2.61, *p* = .010. However, the direction of the relationship reversed. Specifically, following adjustment prenatal exercise was negatively associated with PBQ factor one total score, decreasing the total score by 2.19.

Table 4.11 Unadjusted & adjusted multivariable linear regression showing the association between prenatal health behaviours & the three factors on the PBQ

			p	B	95% CI
Unadjusted	Factor 1	Smoking	.376	1.43	-1.76, 4.63
		Alcohol	.215	.90	-.53, 2.32
		Exercise	**.028**	2.01	.22, 3.80
		Western	.260	-.47	-1.29, .35
		Health Conscious	.067	-.74	-1.54, .05
	Factor 2	Smoking	.916	.08	-1.47, 1.63
		Alcohol	.196	.45	-.24, 1.14
		Exercise	.069	.80	-.06, 1.67
		Western	.558	-.118	-.52, .28
		Health Conscious	.096	-.33	-.71, .06
	Factor 3	Smoking	.193	1.07	-.55, 2.68
		Alcohol	.553	-.22	-.93, .50
		Exercise	.595	.24	-.66, 1.15
		Western	.300	-.22	-.63, .20
		Health Conscious	.376	-.18	-.59, .22
Adjusted	Factor 1	Smoking	.973	.06	-3.29, 3.40
		Alcohol	.250	.85	-.61, 2.32
		Exercise	**.019**	-2.19	-4.02, -.37
		Western	.247	-.50	-1.36, .35
		Health Conscious	.111	-.72	-1.60, .17

4.3.3.2.2. Mother-child relationship

Data were available on the CPRS for 106 participants. The median conflicts total score was 24.00 (IQR = 10.00), the median closeness total score was 45.00 (IQR = 4.00) and the median dependence total score was 11.00 (IQR = 3.00). The distribution of these scores is displayed in Figure 4.10.



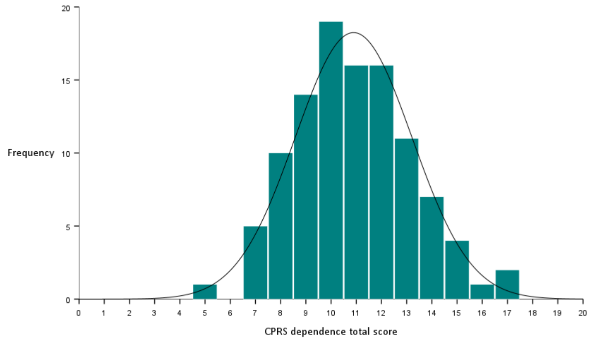


Figure 4.10 Histograms displaying the distribution of total scores on the domains of the Child-Parent Relationship Scale

Linear regression was employed to investigate the relationship between prenatal health behaviours and the three domains on the CPRS (Table 4.12). At the unadjusted multivariable level, conflict domain F(5,97) = 3.55, p = .005, closeness domain F(5,97) = .57, p = .723, dependence domain F(5,97) = 1.24, p = .295, only smoking during pregnancy was significantly positively associated with the conflict domain on the CPRS. This association was adjusted for the same potential confounders utilised in the previous PBQ analysis; maternal age at booking, parity, education (above/below university level) and symptoms of depression. After confirming multicollinearity was not present, the adjusted analysis, F(9,87) = 3.77, p < .001, identified that smoking at any point in pregnancy remained significantly positively associated with the conflict domain, increasing the score by 9.92.

Table 4.12 Unadjusted & adjusted multivariable linear regression identifying the association between prenatal health behaviours & domains on the CPRS.

			p	B	95% CI
Unadjusted	Conflict	Smoking	**<.001**	12.43	5.52, 19.33
		Alcohol	.535	.83	-1.82, 3.48
		Exercise	.703	-.63	-3.86, 2.61
		Western	.239	.86	-.58, 2.31
		Health conscious	.552	.45	-1.05, 1.95
	Closeness	Smoking	.938	.14	-3.33, 3.61
		Alcohol	.897	.09	-1.24, 1.42
		Exercise	.668	.35	-1.28, 1.98
		Western	.316	-.37	-1.09, .36
		Health conscious	.161	-.54	-1.29, .22
	Dependence	Smoking	.104	1.95	-.41, 4.31
		Alcohol	.501	-.31	-1.21, .60
		Exercise	.476	-.40	-1.51, .71
		Western	.298	-.26	-.75, .23
		Health conscious	.379	-.23	-.74, .28
Adjusted	Conflict	Smoking	**.005**	9.92	3.00, 16.84
		Alcohol	.336	1.26	-1.33, 3.86
		Exercise	.866	-.27	-3.42, 2.88
		Western	.442	.57	-.90, 2.05
		Health conscious	.425	.63	-.93, 2.18

4.4. Discussion

4.4.1. Summary

This chapter sought to address Aim two of the thesis, by investigating the influence of maternal health behaviours in pregnancy on short and longer term maternal outcomes. A summary of the main findings regarding the influence of prenatal maternal health behaviours are outlined below.

- Prenatal alcohol consumption was associated with increased likelihood of excessive compared to normal GWG.
- A Western dietary pattern in pregnancy was associated with increased likelihood of depressive symptoms considered to be of clinical significance.
- A Health Conscious dietary pattern in pregnancy was associated with increased likelihood of breastfeeding initiation.
- Undertaking exercise in pregnancy was associated with decreased likelihood of problems with the mother-infant relationship at one year of age.
- Prenatal smoking was associated with increased likelihood of conflict in the mother-child relationship at four years of age.

4.4.2. Gestational weight Gain

GWG or the weight a woman gains during pregnancy is expected and is an indicator of pregnancy progression and fetal growth. However, there is an optimum recommended range (Institute of Medicine, 2009), with GWG outside of this associated with poor outcomes. Within this thesis, it was identified that there was an extremely large range of weight gain of 88.24 kg, with 15% of participants having inadequate GWG, 30.30% normal GWG and 54.70% excessive GWG. Moreover, excessive GWG was the most prevalent category within each BMI classification, with the exception of a healthy BMI in which it was equally prevalent with normal GWG. This indicates that excessive GWG is an issue that is not dependent on pre-pregnancy BMI. This was the first study to investigate GWG in Wales (Garay et al., 2021) and the very high level of excessive GWG in this particular Welsh population is even higher than the 47% determined in the extensive review by Goldstein et al. (2017). It was previously shown there was no difference in GWG in this cohort between indications for ELCS (Garay et al., 2021) potentially minimising the influence of mode of delivery on this outcome. Moreover, as previously discussed in Chapter Two, the GiW sample differed only slightly to the general population that delivered infants at the University

Hospital of Wales during the same time period (Janssen et al., 2018). These points indicate that the cohort is likely to be representative of a wider Welsh population and consequently, the prevalence identified is a cause for concern and GWG may be an issue that requires closer attention in Welsh maternity settings.

Although no health behaviours were found to influence overall GWG, consuming alcohol in pregnancy was associated with increasing the risk of excessive compared to normal GWG. However, it should be noted that whilst this association remained significant following adjustment for potential confounders, the direction of the relationship changed. This may indicate that the factors utilised as confounders (prenatal depression, BMI at booking and income) are highly influential in this relationship which should be taken into consideration. Nevertheless, it does not overtly detract from alcohol consumption being an important influence on GWG outcomes in Wales. Overall, there has been little research investigating the influence of alcohol in this area. Even studies investigating a range of predictors often did not include alcohol, for example Suliga et al. (2018). Indeed, a recent in depth review highlighted that there have been no intervention studies with a focus on alcohol (Hayes et al., 2021). Previous studies such as that by Deputy et al. (2015) in America and Gaillard et al. (2013) in Rotterdam, found no association between alcohol consumption and GWG outcomes. However, this is an under researched area and no research has previously investigated this in the UK, or with multiple health behaviours, thus our findings, although different are adding to the existing literature.

No association was identified between smoking, exercise or dietary patterns and GWG outcomes. Existing research in these areas often reaches contradictory findings, thus the current findings are not entirely unexpected. In relation to dietary patterns, a recent systematic review and meta-analysis by Abdollahi et al. (2021) concluded that there was insufficient data to investigate the association with GWG outcomes. It was also determined that existing literature was of low quality due to heterogeneity and lack of adjustment for confounders. As such, our current finding is developing the research base. Regarding prenatal exercise, the literature in this area largely consists of RCTs, which whilst important do not necessarily reflect real world pregnancy behaviours. Thus, it is important that whilst an umbrella review consisting overwhelmingly of RCTs concluded that there was strong evidence that exercise is associated with positive outcomes (DiPietro et al., 2019), the literature from observational studies was more varied. Some studies, such as that by Gimunová et al. (2018) utilising the large European Longitudinal Study of Pregnancy and

Child (ELSPAC) cohort data found that exercise decreased GWG, whilst other such as Chasan-Taber et al. (2014) in America found no association with GWG outcomes, thus supporting our finding. Similarly, in relation to smoking in pregnancy the literature is again highly varied in its conclusions. Some studies identified a negative association, with smoking increasing the risk of excessive GWG (Gaillard et al., 2013). Others, in support of our findings, found no association to be present in a range of countries (Fealy et al., 2020, Wells et al., 2006, Suliga et al., 2018). Although there are inconsistencies between the current findings and some previous research in these areas, no prior research has been conducted in the UK. As such, our findings may simply be accurately reflecting the nature of the relationship here and consequently provide the necessary improvement in the knowledge base.

Overall, it has been identified that there is a high prevalence of excessive GWG in Wales and that unhealthy behaviours, specifically consuming alcohol in pregnancy, can influence GWG outcomes. Given that no previous research has investigated this topic in the UK, and the literature is full of inconsistencies and limited research, this evidence has contributed significantly to the research area

4.4.3. Maternal mental health

It has been highlighted that maternal mental health conditions are highly prevalent in the prenatal period. In the current research 13.80% of participants had depressive symptoms of clinical significance, whilst 27.70% had clinically significant levels of anxiety. These rates are similar to previous research investigating the prevalence of prenatal mental health conditions. For example, in another study recently published utilising Welsh data, which was worked upon during this PhD, levels of depression and anxiety were identified at 15.60% and 22.20%, respectively (Savory et al., 2021). Within the GiW cohort, prenatal health behaviour, specifically dietary patterns, influenced maternal mental health, but only for prenatal depression symptoms and not anxiety symptoms. Historically, prenatal anxiety has received far less research attention compared to depression, despite the conditions frequently co-occurring and anxiety being the more prevalent condition. Therefore, the current research contributes to the understanding of the influence of health behaviours in pregnancy on both prenatal depression and anxiety.

Within the GiW cohort, consuming a Western dietary pattern in pregnancy was associated with increased likelihood of recording clinically significant levels of prenatal depression symptoms. That this association was not present when considering overall EPDS scores supports the importance of investigating both continuous and binary outcomes where possible in research. As with the majority of outcomes investigated within this thesis, the existing literature regarding the influence of dietary patterns is mixed. Some studies identify that healthy dietary patterns are associated with improved mental health outcomes. For example, Huang et al. (2021) recently identified that in a large Chinese cohort, healthier dietary patterns were associated with reduced risk of prenatal depression symptoms. The current study did not find a similar association with a Health Conscious dietary pattern. Fewer studies identify an association with a Western dietary pattern. This is highlighted by two systematic review and meta-analyses (Lai et al., 2014, Silva et al., 2019) that concluded that currently there is no definitive evidence of an influence of a Western dietary pattern on maternal mental health. However, it is important to note that both studies acknowledge that this is due to a lack of existing research within this area, rather than confirming no influence exists. Indeed, a previous study by Pina-Camacho et al. (2015) did reassuringly identify a relationship between prenatal depression symptoms and unhealthy dietary patterns in a UK population, albeit in an alternate direction of causality. This is also similar to the findings of Rachel et al. (2017). In light of all this, our finding of an influence of prenatal dietary patterns, specifically an unhealthy Western dietary pattern, is enhancing the evidence within this area.

Although the current research did not identify an association between any other health behaviour and maternal mental health outcomes, this is reflective of the inconsistent nature of the existing literature. The findings of a lack of association are supported by some previous research. Indeed, in relation to prenatal exercise, Wilson et al. (2020) in a UK cohort also found no association between physical activity and depression in pregnancy. Moreover, studies such as Brittain et al. (2015) which utilised data from the Drakenstein Child Health Study, a birth cohort in South Africa, found no association between alcohol use in pregnancy and prenatal depression symptoms. However, there have also been studies that have identified different findings to the current research, especially in regards to smoking, in which recent reviews have highlighted an overall negative relationship between prenatal smoking and both prenatal depression and anxiety (Biaggi et al., 2016, Silva et al., 2017). These alternative findings do not indicate that the current research is inaccurate or any less important. Indeed, it is reassuring that a previous UK study identified similar findings (Wilson et al., 2020). Instead, it could be a product of the high level of heterogeneity within the evidence base, an issue that has arisen throughout this thesis. Indeed, with maternal mental health, differences between studies occur in relation to timepoints of measures, populations studied and importantly also the measures of mental health. In fact, across this research measures of prenatal mental health vary not only by type but importantly also by the scores utilised to classify high risk categories on the same measure. These factors could all be contributing to the inconsistent findings. Moreover, as with other outcomes studied within this thesis, research rarely incorporates multiple health behaviour simultaneously, the use of which in the current study may have provided more accurate findings. Thus, this research provides further understanding of the influence of prenatal health behaviours on depression and anxiety symptoms in pregnancy.

An important point that should be considered in this area of research is that of the direction of causality in the relationship. This research, and much of the existing literature base has investigated the influence of health behaviours on mental health outcomes. However, it is entirely possible that conversely, mental health symptoms may actually influence the health behaviours in pregnancy. Indeed, a previous study by Pina-Camacho et al. (2015) identified that prenatal depression symptoms were associated with higher adherence to unhealthy dietary patterns in pregnancy in the Avon Longitudinal Study of Parents and Children (ALSPAC) cohort. Whilst beyond the scope of this thesis, it would be interesting in the future to investigate the direction of causality within the Grown in Wales cohort to further enhance our understanding.

Overall, this study has identified that there is a relationship between negative health behaviours in pregnancy and suboptimal perinatal mental health outcomes. Specifically, a Western dietary pattern was associated with increased risk of clinically significant symptoms of depression in pregnancy. Alternatively, prenatal health behaviours were not found to influence anxiety symptoms. Given that the existing literature largely neglects anxiety, and the evidence base for both conditions is inconsistent, this research contributes to the knowledge base overall and particular in regards to Welsh populations.

4.4.4. Maternal care

4.4.4.1. Breastfeeding

Breastfeeding is considered a crucial component of maternal care, providing the infant with optimal nutrition and developing the bond between mother and child. However, despite the significant advantages associated with breastfeeding, many women do not follow the recommended guidance. It has previously been highlighted that the UK had the lowest breastfeeding rate in the world, with Wales the lowest of the UK nations (Steering, 2016). In response to this the Welsh Government introduced the All Wales Breastfeeding Five Year Action Plan to improve breastfeeding outcomes (Welsh Government, 2019a). The current research identified breastfeeding initiation rates of 71.10%, with 67.30% of these participants continuing to breastfeed at six months postpartum. These figures are higher than those identified in a Welsh Government report, which highlighted initiation rates of 63.50%, a rate which has increased in recent years as well as a rate of breastfeeding at six months of 25.30% (Welsh Government, 2021). There is a considerable difference between the rates at six months, which would be explained by the nature of the data. The continuation rate in this thesis refers only to those who initiated, whereas the Government rate refers to all participants, including those who didn't initiate. Nevertheless, our findings provide additional insight into this area. Whilst the prevalence rate is reassuringly higher than that identified in previous years, given the importance of breastfeeding there is clearly still requirement for rates to be improved further.

The current research identified that in the GiW cohort, only a Health Conscious dietary pattern in pregnancy was associated with breastfeeding initiation. No prenatal health behaviours were associated with breastfeeding duration after adjustment for potential confounding factors. Overall, with the exception of smoking there is a significant lack of existing research investigating this important area. Indeed, only one previous study was identified that investigated the influence of dietary patterns, albeit *a priori*, with breastfeeding outcomes (Rosito et al., 2014). In support of our findings, this study, conducted with 820 participants in Brazil, also identified that a healthy compared to unhealthy dietary pattern influenced breastfeeding, although in relation to duration rather than initiation. Given that types of behaviour tend to cluster together, as discussed in Chapter One, it is possible that this association is due to those women who are choosing healthier diets also being more aware of and more inclined to undertake additional healthy behaviours related to their infant. In this case, breastfeeding. Thus, although further research is required, it appears that healthy dietary patterns in pregnancy may positively influence breastfeeding outcomes.

However, no influence was found for prenatal smoking, alcohol consumption or exercise. This is not an expected finding, especially in relation to exercise and alcohol consumption, where there is a very limited research base in this area. Again, this limited literature makes conducting comparisons difficult. Nevertheless, the current findings regarding alcohol consumption are supported by previous research by McLeod et al. (2002)

in New Zealand and Chimoriya et al. (2020) in Australia. These studies also identified no association between prenatal alcohol consumption and breastfeeding initiation or duration. Regarding exercise, the findings of the current research differ to that in the only two previous studies in this area. Indeed, whilst we found no association, both Villar et al. (2018) and Nguyen et al. (2017) found exercise in pregnancy to be associated with increased likelihood of breastfeeding initiation and duration respectively. It is important to consider, however, that the research by Nguyen et al. (2019) may not be generalisable to other countries given the populations' extremely high breastfeeding rates. It is also possible that this difference in findings is due to differences in how exercise is measured and defined. Overall, it can be seen that there is extremely limited evidence in this area. As such this research enhances the current literature however additional research is required to fully understand the influence of these health behaviours.

Prenatal smoking was also found to not influence breastfeeding outcomes. The influence of this health behaviour is the most highly researched in this area. Unlike the finding within the GiW cohort, the current trend appears to indicate that prenatal smoking is associated with poorer breastfeeding outcomes. For example, a large study in Australia of 7491 participants identified that women who smoked during pregnancy were less likely to initiate breastfeeding (Bish et al., 2021). Furthermore, a systematic review and meta-analysis concluded that despite heterogeneity being an issue between studies, there was compelling evidence that prenatal smoking was a strong predictor of both breastfeeding initiation and duration (Cohen et al., 2018). Nevertheless, although perhaps less common, studies have found no association with smoking, thus supporting the current findings. Indeed, Arora et al. (2017) identified no effect of prenatal smoking on breastfeeding outcomes after adjusting for confounding variables, thereby suggesting additional factors are more influential on breastfeeding. Moreover, although there are different findings, this does not detract from the importance of the current research. As with other areas investigated, previous research does not consider multiple health behaviours simultaneously, thus the research here may be providing a more accurate representation of the relationship. The possibility of a dose response in this area has also been noted (Dennis, 2002). It would be interesting to investigate this line of enquiry in future analysis of the GiW cohort, to further enhance the understanding this thesis provides.

In summary, with the exception of smoking there has been very little research on the influence of prenatal health behaviours on breastfeeding. The findings here indicate that healthier prenatal behaviours are associated with more positive breastfeeding outcomes. Given the lack of research in general, but also in Wales, this research contributes to the current understanding in this area.

4.4.4.2. Mother-infant/child relationship

The relationship that forms between a mother and their child after birth has been argued to be one of the most important processes that occur in the early stages of life (Brockington, 2004). However, despite what is known regarding the influence of the pregnancy environment on a range of outcomes, research typically fails to examine prenatal risk factors in this area. Indeed, it was not possible to identify any literature that has previously examined the potential influence of prenatal maternal health behaviours on this early relationship. This thesis examined this area by focusing on early maternal-infant bonding, which is reflective of the overall relationship, and the later maternal-child relationship. Overall, on the PBQ measured at one year of age, there were a range of scores on each of the factors, however generally there were very few participants within the categories classified as high risk. This variety of scores within the healthy range was also true for the CPRS, measured at four years of age. This indicates within the GiW cohort, the mother-infant/child relationships can be considered healthy.

Regarding the influence of health behaviours, after adjustment for potentially confounding variables it was determined that exercise in pregnancy was associated with both overall PBQ scores and Factor one scores. From this it can be inferred that undertaking prenatal exercise improves both the overall mother-infant bond and general bonding in the relationship. Interestingly however, in regards to the overall PBQ score, exercise only became significant at the $p = .05$ level after adjustment for the potentially confounding variables of prenatal maternal depression symptoms, maternal age, education and parity. This may suggest that these confounding variables are highly influential in the maternal-infant/child relationship. Nevertheless, this evidence provides crucially required foundational knowledge base within this area. Furthermore, by utilising the CPRS it was demonstrated that prenatal smoking strongly influences the mother-child relationship. Specifically, prenatal smoking was significantly associated with greatly increased likelihood of conflict within the mother-child relationship. Unfortunately, it is not possible to discuss this research in the context of the existing literature, as there has been no previous studies conducted.

From this research it appears that prenatal health behaviours influence the mother-infant/child relationship. Specially, healthy behaviour appears to be associated with improved outcomes, and negative behaviour with suboptimal outcomes. As it was not possible to identify any previous evidence within this research area, the research within this thesis provides an important basis upon which crucial further research can occur.

4.4.5. Conclusion

This chapter sought to investigate the influence of prenatal health behaviours on a range of maternal outcomes. Although true that causality cannot be determined, as discussed in Chapters Two and Six, in support of the hypotheses proposed in Chapter One overall it was determined that healthy prenatal behaviours were associated with positive outcomes and unhealthy prenatal behaviours were related to suboptimal outcomes. This research addressed a significant gap in the research in relation to the outcomes of interest, given that the literature base is inconsistent and frequently lacking. Limitations of the research related to the cohort were addressed in Chapter Two. Overall, the evidence within this chapter has improved the current understanding of the influence of prenatal health behaviours on maternal outcomes, both in general and in Wales.

Chapter 5 - Prenatal health behaviours & infant outcomes

5.1. Introduction

It has been emphasised throughout that the environment during pregnancy can have long lasting implications for both mother and child. Maternal health behaviours are an important example of modifiable environmental influences. The previous chapters focussed on the maternal health behaviours present within the Grown in Wales (GiW) cohort and the influence of these health behaviours on maternal outcomes. In this chapter, the influence on infant outcomes will be examined, with a specific focus on the immediate birth outcomes of APGAR scores and birthweight measures, as well as on longer term infant neurodevelopment and temperament. As previously highlighted, these outcomes are not only important in themselves but are also all associated with further health and developmental outcomes. For example, a low birthweight (LBW) or small for gestational age (SGA) birth is associated with increased risk of maternal cardiovascular disease (Eskild, 2018) and in the infant increased lifelong morbidity (Flamant and Gascoin, 2013). Consequently, understanding how maternal prenatal health behaviours influence infant outcomes could be beneficial for lifelong health and development.

A thorough overview of the current evidence in this area was provided in Chapter One. Similar to the previous chapter, the existing research is often contradictory and in certain cases limited in its availability. In summary, overall prenatal smoking appears to be consistently associated with birthweight outcomes, whilst exercise is generally identified to have no effect. However, evidence for the effect of dietary patterns and alcohol consumption is often contradictory. Moreover, the research rarely utilises fully customised birthweight centiles despite the advantages of this over traditional measures. Thus, it is difficult to draw accurate conclusions. There is also only limited evidence available for the effect of smoking, alcohol and dietary patterns on APGAR scores, whilst the slightly increased interest in the influence of exercise on APGAR scores again suggests no effect. Regarding neurocognitive development, there is a paucity of literature available on exercise and no evidence for the influence of dietary patterns. Research appears to suggest that there is no effect associated with alcohol, whilst the evidence base for smoking is mixed. Finally, little research has investigated temperament. Although smoking and alcohol appear to be associated with suboptimal outcomes, there is a clear lack of research focusing on dietary patterns and exercise. Throughout this area of research there is also an issue of heterogeneity between studies. Finally, as with all sections of this thesis, there is a severe paucity of research investigating the influence of these health behaviours on infant outcomes in Welsh populations.

As stated throughout, this thesis intends to explore the limitations and gaps in the existing literature and provide additional insight into areas with contrasting findings. Following on from Chapter Four, this chapter will continue to consider the second research question: What is the influence of the maternal health behaviours in pregnancy on maternal and infant outcomes? Again, the following hypotheses will be investigated 1) Healthy maternal health behaviours in pregnancy are associated with positive maternal and infant outcomes 2) Unhealthy maternal health behaviours in pregnancy are associated with negative or suboptimal maternal and infant outcomes. To address these hypotheses, Aim three of the thesis will be utilised.

Aim 3. To assess the influence of maternal health behaviours in pregnancy on short & longer term infant health and development.

- To investigate the association between maternal prenatal health behaviours and immediate birth outcomes in the form of birthweight, custom birthweight centiles (CBWC) and APGAR scores.
- To assess the association between maternal prenatal health behaviours and infant neurodevelopment in the form of cognition and language ability.
- To consider the association between maternal prenatal health behaviours and infant and child temperament.

5.2. Method

5.2.1. Participants

As with previous chapters, 348 participants were initially eligible for inclusion following the exclusion of the seven participants that withdrew from the cohort. The same additional eligibility criteria that were applied to Chapter Four are also relevant for the current chapter. All analyses required participants to be of Caucasian ethnicity, with the infants gestational age ≥ 37 weeks. Additionally, for analyses utilising Y1 data infants had to be aged < 18 months, and for both Y1 and Y4 analyses infants were included if there was no diagnosed developmental issues or serious health conditions. Overall, 312 participants were eligible for the A1 questionnaire, 116 for the Y1 questionnaire, 73 for the Y1 assessment and 131 for Y4 questionnaire analyses. Consistent with previous chapters, due to the variation in data availability between measures the specific participant numbers involved in each analysis are outlined at the start of each analysis subsection to ensure clarity.

5.2.2. Materials

The materials have been outlined in depth in Chapter Two. The A1 questionnaire provided data on the health behaviours of alcohol consumption (categorical), smoking (categorical) and exercise (categorical) in pregnancy. As with previous chapters and in line with existing research, the smoking and alcohol variables for trimester one and trimesters two and three were combined into the variables "smoking at any point in pregnancy" and "alcohol at any point in pregnancy", scored as 'yes' or 'no' (categorical). These variables were utilised within this chapter. Dietary patterns (continuous) were obtained from the food frequency questionnaire (FFQ), with the process of obtaining the patterns outlined in Chapter Three.

Data on birthweight (continuous and categorical; Low birthweight (LBW)/Average birthweight (ABW)/High birthweight (HBW)) was obtained from the midwife recorded medical notes that were collected at the A1 timepoint. As outlined in previous chapters, CBWC (continuous and categorical: Small for gestational age (SGA)/average for gestational age(AGA)/large for gestational age(LGA)) were later calculated utilising the GROW bulk centile calculator (UK) (Gardosi and Francis, 2016). In addition to birthweight, this required further data from the midwife recorded notes on maternal ethnicity (categorical: Caucasian/Non-Caucasian), parity (categorical: Nulliparous/Multiparous), height (continuous) and weight (continuous) as well as infant gender (categorical: Male/Female) and gestational age (continuous). The APGAR scores at one minute and five minutes were also obtained from the midwife recorded notes (continuous and categorical: Nine or less/10 & seven-nine/10).

The Y1 timepoint also provided data on infant temperament and neurodevelopment. As part of the Y1 questionnaire, participants completed the Cardiff Infant Contentiousness Scale (CICS) (Hay et al., 2010), developed to assess early manifestations of anger (continuous), and the Infant Behaviour Questionnaire-Revised-Short form (IBQ-R-SF) (Putnam et al., 2014), which examined domains of infant temperament by maternal self-report. Definitions for the three major domains and 14 subdomains are outlined in Chapter Two. Only the major domains of negative affectivity, surgency and regulatory capacity are incorporated in this analysis (continuous). Temperament was also assessed during the Y1 infant assessment, through tasks adapted from the Laboratory Temperament Assessment Battery (LabTAB) (Goldsmith and Rothbart, 1996). The specific tasks utilised were the Novel Toy, Sustained Attention and Maternal Separation tasks (continuous). Data on age standardised cognition, receptive language and expressive language were also available from the Y1 assessment (continuous), through the use of the Bayleys Scales of Infant Development Third Edition (BSID-III) (Bayley, 2009). Language was assessed during the LabTAB tasks, whilst cognition was assessed through the completion of specifically designed tasks. All measures from the Y1 timepoint have been outlined in Chapter Two.

The Y4 questionnaire provided further data regarding infant temperament, through the inclusion of the Child Behaviour Questionnaire-Short Form (CBQ-SF) (Putnam and Rothbart, 2006), developed as a continuation of the IBQ. The CBQ-SF is outlined fully in Chapter Two, including the provision of definitions of three major and 15 subdomains of early childhood temperament the questionnaire assesses. The three major domains of negative affectivity, surgency/extraversion and effortful control were utilised in this analysis (continuous).

The potentially confounding variables that were included in the different adjusted analyses were incorporated on the basis that the literature review identified them as influential for that outcome, previous papers from the GiW study found them to be influential or on the advice obtained through peer review. For the adjusted birthweight outcome analysis these confounders included maternal age (continuous), gestational diabetes (GDM, categorical: Yes/No), mode of conception (categorical: Natural/Assisted), gestational age (continuous) and Welsh Index of Multiple Deprivation (WIMD) score (continuous). For the adjusted cognition and language development analysis this included parity (categorical: Nulliparous/Multiparous) and WIMD score (continuous). Finally, for all adjusted temperament analyses the confounding variables were again parity (categorical: Nulliparous/Multiparous) and WIMD score (continuous). These variables are all outlined in detail in Chapter Two and were obtained from either the A1 questionnaire or the midwife recorded notes.

5.2.3. Statistical analysis

Variable normality was assessed via the use of histograms, skewness, kurtosis, Kolmogorov-Smirnov and Shapiro-Wilk values. Descriptive statistics for outcome variables were provided based on the normality assessment. Linear and binary multivariable regression analyses were utilised where relevant to investigate the associations between health behaviours and the various outcomes assessed in this chapter. The unadjusted and adjusted models here utilise method two as outlined in section 2.1.6. Model assumptions as outlined in Chapter Two were assessed and found to not be violated. Initially, all analyses were undertaken at the unadjusted multivariable level. Analyses significant at the unadjusted level were adjusted for potential confounders identified from the literature, or in the case of birthweight from peer review guidance, following confirmation that multicollinearity was not present. Multicollinearity was assessed via correlation coefficients or VIF and tolerance scores. Here, the independent variables were the five health behaviours (unadjusted model) and the five health behaviours and confounding variables (adjusted model), whilst the dependent variables were the infant outcomes of interest.

5.3. Results

5.3.1. Birthweight

As outlined previously in Chapter Three, the median CBWC was 58.60 (IQR = 48.90). In terms of classifications, 23 (7.40%) were classified as SGA, 245 (78.20%) AGA and 44 (14.10%) LGA. When considering traditional birthweight classifications, the median birthweight was 3.51 kg (IQR = .65), with 8 (2.6%) classified as LBW, 247 (79.20%) as normal birthweight and 57 (18.30%) as HBW. The distribution of CBWC and birthweight (kg) are displayed in Figure 5.1, whilst the frequency of participants classified by CBWC and traditional birthweight classifications are displayed in Figure 5.2.

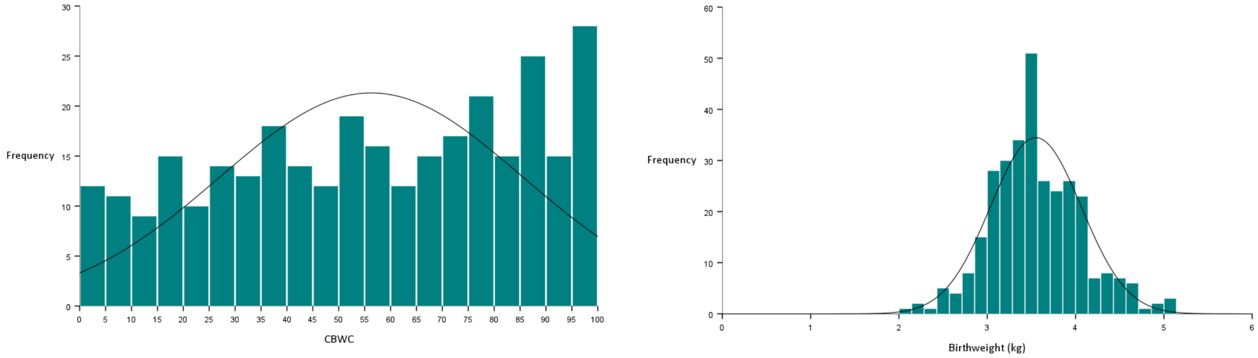


Figure 5.1 The distribution of overall custom birthweight centiles & birthweight (kg).

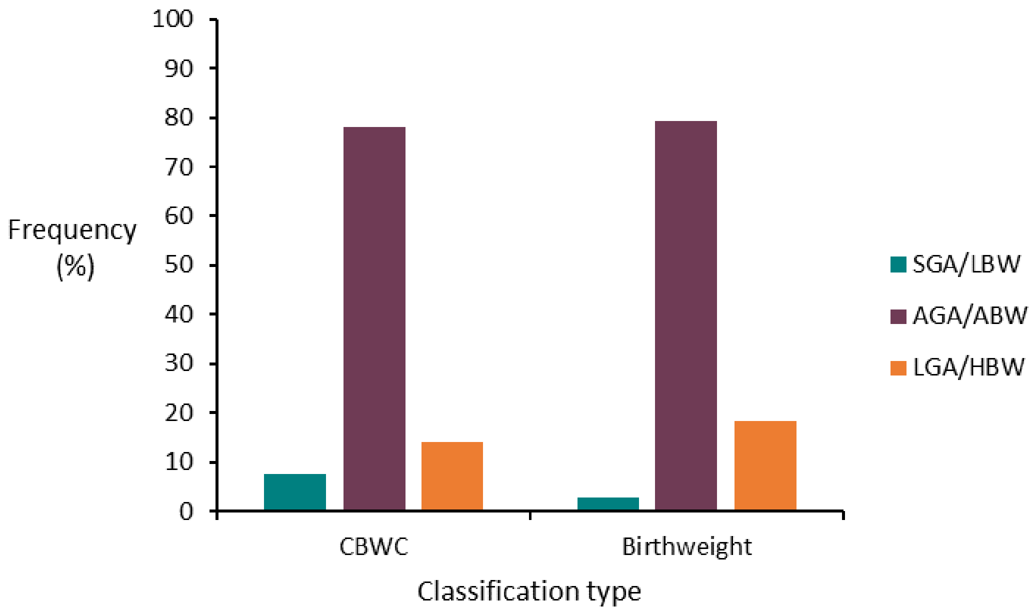


Figure 5.2 The frequencies of classifications within both custom birthweight centile & traditional population based measures of birthweight

5.3.1.1. Traditional birthweight classifications

Linear regression was employed to investigate the association between health behaviours and overall birthweight (kg) (Table 5.1). In the unadjusted multivariable analysis, F(5,288) = 4.48, $p < .001$, smoking in pregnancy, exercise and a Health Conscious dietary pattern were associated with overall birthweight. This analysis was adjusted for the same potential confounders utilised in Chapter Three; maternal age, GDM diagnosis, mode of conception, WIMD score and gestational age. These were identified from the literature and on the advice of reviewers during the peer review process for Garay et al. (2019). Once adjusted for potential confounders and multicollinearity was found not to be present, the multivariable analysis, F(10,265) = 4.80, $p < .001$, identified that only a Health Conscious dietary pattern remained significantly associated with overall birthweight, with a one unit increase in Health Conscious dietary pattern score associated with an increase in birthweight of .08 kg.

Table 5.1. Unadjusted & adjusted multivariable linear regression identifying associations between maternal health behaviours in pregnancy & overall birthweight

		p	B	95% CI
Unadjusted	Smoking	**.007**	-.27	-.47, -.07
	Alcohol	.934	.01	-11, .12
	Exercise	**.049**	-.16	-.32, .00
	Western	.219	-.04	-.10, .02
	Health conscious	**.002**	.09	.03, .15
Adjusted	Smoking	.067	-.19	-.39, .01

	p	B	95% CI
Alcohol	.561	-.04	-.16, .09
Exercise	.066	-.15	-.30, .01
Western	.559	-.02	-.08, .04
Health conscious	**.021**	.08	.01, .14

It was not possible to investigate the association between maternal health behaviours in pregnancy and the LBW classification due to the low number of participants (N =8) classified as LBW. However, binary regression was utilised to consider the relationship between health behaviours and HBW compared to ABW classifications (Table 5.2). At the unadjusted multivariable level, $\chi^2(5) = 4.76$, $p = 4.76$, there were no significant associations between health behaviours in pregnancy and delivering a HBW compared to ABW infant. As such further adjustment for potential confounders was not undertaken.

Table 5.2. Unadjusted multivariable binary regression identifying associations between maternal health behaviours in pregnancy & HBW compared to ABW

	p	Exp (B)	95% CI
Smoking	.135	.32	.07, 1.43
Alcohol	.997	1.00	.54, 1.86
Exercise	.231	.58	.24, 1.42
Western	.615	.92	.68, 1.26
Health conscious	.585	1.09	.80, 1.49

5.3.1.2. CBWC classifications

Linear regression was utilised to investigate the association between maternal health behaviours and overall CBWC (Table 5.3). At the multivariable unadjusted level, $F(5,288) = 5.27$, $p < .001$, smoking in pregnancy, exercise in pregnancy and a Health Conscious dietary pattern were associated with CBWC. This analysis was adjusted for the potential confounders of maternal age, GDM, mode of conception and WIMD score. After adjustment for confounders and ensuring multicollinearity was not present, $F(9,266) = 3.40$, $p < .001$ multivariable linear regression identified that smoking in pregnancy was significantly associated with a decrease in CBWC of 16.80. Undertaking exercise in pregnancy was significantly associated with a 9.96 increase in CBWC, whilst a one unit increase in Health Conscious dietary pattern score was associated with an increase in CBWC of 4.76.

Table 5.3. Unadjusted & adjusted multivariable linear regression identifying associations between maternal health behaviours in pregnancy & overall CBWC

		p	B	95% CI
Unadjusted	Smoking	**.003**	-16.80	-27.90, -5.72
	Alcohol	.475	-2.44	-9.17, 4.28
	Exercise	**.035**	9.65	.71, 18.60
	Western	.166	-2.33	-5.62, .97
	Health conscious	**.002**	5.45	2.07, 8.83
Adjusted	Smoking	**.015**	-14.60	-26.37, -2.83
	Alcohol	.306	-3.63	-10.59, 3.34
	Exercise	**.032**	9.96	.86, 19.05
	Western	.247	-2.04	-5.51, 1.42
	Health conscious	**.011**	4.76	1.08, 8.45

Binary regression was employed to investigate the association between SGA compared to AGA CBWC classifications (Table 5.4). At the unadjusted multivariable level, $\chi^2(5) = 17.88$, $p = .003$, smoking and a Health Conscious dietary pattern were associated with a SGA compared to an AGA birth. This analysis was adjusted from the same confounders outlined previously. After adjustment, $\chi^2(9) = 24.78$, $p = .003$, only a Health Conscious dietary pattern remained significantly associated with being born SGA compared to AGA. Specifically, a one unit increase in Health Conscious dietary pattern score was associated with reduced odds of delivering an SGA compared to AGA baby by a factor of .44.

Table 5.4. Unadjusted & adjusted multivariable binary regression identifying associations between maternal health behaviours in pregnancy & being born SGA compared to AGA

		p	Exp (B)	95% CI
Unadjusted	Smoking	**.024**	3.44	1.17, 10.08
	Alcohol	.873	.93	.35, 2.42
	Exercise	.465	.60	.15, 2.39
	Western	.302	1.26	.81, 1.97
	Health conscious	**.003**	.44	.26, .75
Adjusted	Smoking	.118	2.85	.77, 10.60
	Alcohol	.948	1.04	.34, 3.15
	Exercise	.582	1.62	.29, 8.92
	Western	.781	1.08	.64, 1.80
	Health conscious	**.013**	.45	.24, .85

A similar analysis was undertaken to investigate the association between maternal health behaviours and an LGA compared to AGA birth (Table 5.5). Unadjusted multivariable binary regression, $\chi^2(5) = 16.79$, $p = .005$, identified that only alcohol was significantly associated with being born LGA compared to AGA. When adjusted for the same confounders outlined in the previous analyses and confirming multicollinearity was not present, the adjusted analysis, $\chi^2(9) = 21.28$, $p = .011$, revealed that alcohol consumption during pregnancy remained significantly associated with delivering an LGA compared to AGA baby, specifically reducing the odds by a factor of .31.

Table 5.5. Unadjusted & adjusted multivariable binary regression identifying associations between maternal health behaviours in pregnancy & being born LGA compared to AGA

		p	Exp (B)	95% CI
Unadjusted	Smoking	.998	.00	.00, .00
	Alcohol	**.013**	.37	.16, .81
	Exercise	.584	1.30	.54, 3.75
	Western	.780	.96	.76, 1.52
	Health conscious	.099	1.33	.89, 1.84
Adjusted	Smoking	.998	.00	.00, .00
	Alcohol	**.008**	.31	.13, .73
	Exercise	.376	.62	.22, 1.79
	Western	.660	1.09	.75, 1.59
	Health conscious	.448	1.17	.78, 1.76

5.3.2. APGAR scores

5.3.2.1. APGAR score at one minute

This analysis involved data from 311 participants. There was a median overall one minute APGAR score of nine (IQR = .00) (Figure 5.3) and when utilising the traditional classification system, six participants (1.9%) scored below the ‘normal’ range i.e. less than seven, whilst 305 (98.10%) scored within the ‘normal’ range i.e. seven or above. Further examination of the ‘normal’ classification identified that 31 participants (10.20%) scored in the low ‘normal’ range i.e. seven to nine, whilst 274 (89.80%) achieved the highest possible score of 10. Due to the low number of participants scoring outside of the ‘normal’ range (N = 6), it was not possible to examine the association of health behaviours with only this group. Instead, this analysis focused on the association between health behaviours and overall one minute APGAR scores and APGAR scores of nine or less compared to 10 and scores of seven to nine compared to 10.

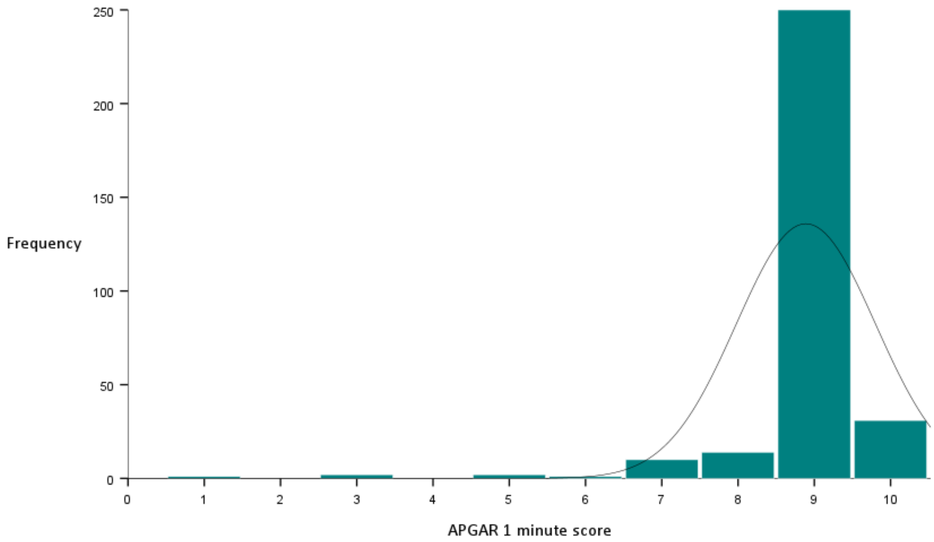


Figure 5.3 The distribution of APGAR scores at one minute

Linear regression was utilised to investigate the relationship between health behaviours and overall APGAR scores at one minute after birth (Table 5.6). The unadjusted multivariable analysis, $F(5,287) = .37$, $p = 868$, revealed no associations between any health behaviours and overall one minute APGAR scores. As such, further analysis adjusting for confounding variables was deemed unnecessary.

Table 5.6. Unadjusted multivariable linear regression to identify the association between health behaviours in pregnancy & overall APGAR scores at one minute

	p	B	95% CI
Smoking	.976	.976	-.36, .37
Alcohol	.907	.907	-.21, .24
Exercise	.796	.796	-.33, .26
Western	.264	.264	-.05, .17
Health Conscious	.518	.518	-.08, .15

Binary regression was employed to assess the relationship between health behaviours in pregnancy and APGAR scores at one minute of nine or less compared to 10 as well as scores of seven to nine compared to 10 (Table 5.7). Unadjusted multivariable binary regression identified no significant associations between health behaviours and either APGAR score outcomes, nine or less compared to 10, $\chi^2(5) = 5.96$, $p = .310$, or seven to nine compared to 10, $\chi^2(5) = 5.99$, $p = .307$. Due to the lack of associations, it was unnecessary to adjust the analysis further for potential confounding variables.

Table 5.7. Unadjusted multivariable binary regression to identify the association between health behaviours in pregnancy & APGAR scores at one minute of nine or less compared to 10 & scores of seven to nine compared to 10

		p	Exp (B)	95% CI
9 or less vs 10	Smoking	.206	3.81	.48, 30.27
	Alcohol	.119	2.06	.83, 5.13
	Exercise	.642	.78	.27, 2.27
	Western	.106	.74	.49, 1.13
	Health Conscious	.800	1.06	.69, 1.62
7 to 9 vs 10	Smoking	.200	3.87	.49, 30.73
	Alcohol	.112	2.09	.84, 5.18
	Exercise	.652	.78	.27, 2.28
	Western	.188	.76	.50, 1.15
	Health Conscious	.773	1.07	.70, 1.63

5.3.2.2. APGAR scores at five minutes

Data from 311 participants was included in this analysis. The median overall APGAR score at five minute was 10.00 (IQR = .00) (Figure 5.4). Utilising the traditional classification system two participants (.06%) scored below the ‘normal’ range i.e. less than seven, with 309 (99.40%) participants scoring within the ‘normal’ range i.e. seven or above. Additionally, 34 (11.00%) scored in the low ‘normal’ range i.e. seven to nine, whilst 275 participants (89.00%) achieved the maximum score of 10. Due the very low number of participants scoring outside of the ‘normal’ range (N = 2), the analysis focused on the association between health behaviours and overall APGAR scores at five minutes, scores of nine or less compared to 10 and finally scores in the low ‘normal’ range of seven to nine compared to 10.

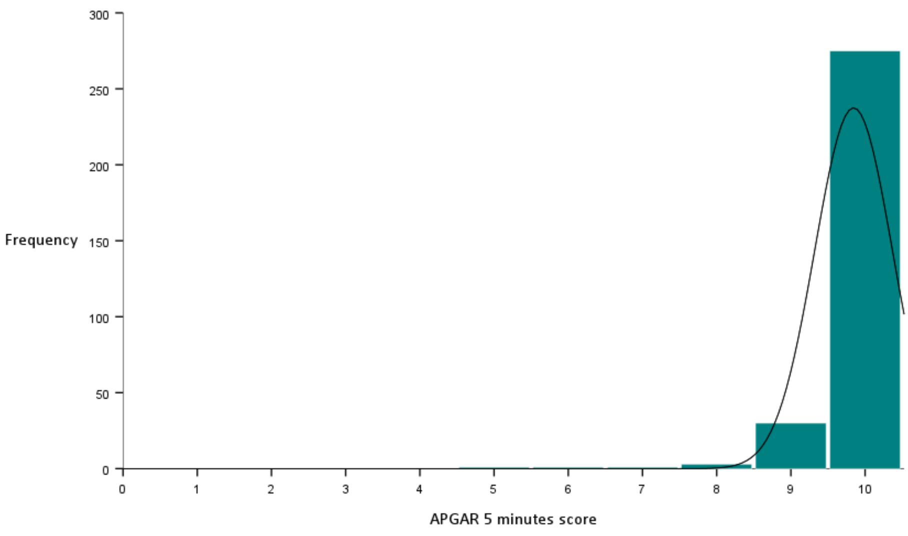


Figure 5.4 The distribution of APGAR scores at five minutes.

A similar analysis as that utilised for the APGAR scores at one minute was undertaken to investigate the association between health behaviours and APGAR scores at five minutes (Table 5.8). Unadjusted multivariable linear regression was used to investigate the association with overall APGAR scores at five minutes, $F(5,287) = .73$, p = 601. No significant associations between health behaviours and overall APGAR scores at five minutes were identified and as such no further analysis for confounding variables was undertaken.

Table 5.8. Unadjusted multivariable linear regression to identify the association between health behaviours in pregnancy & overall APGAR scores at five minutes

	p	B	95% CI
Smoking	.677	.05	-.17, .26
Alcohol	.551	.04	-.09, .17
Exercise	.729	-.03	-.20, .14
Western	.482	.02	-.04, .09
Health conscious	.149	.05	-.02, .11

To investigate the relationship between health behaviours in pregnancy and APGAR scores at five minutes of nine or less vs 10 and seven to nine vs 10, binary regression was utilised (Table 5.9). At the unadjusted multivariable level, there were no significant associations between health behaviours and either of the APGAR score outcomes, nine or less compared to 10, $\chi^2(5) = 2.54$, $p = .771$, or seven to nine compared to 10, $\chi^2(5) = 1.56$, $p = .906$. As such, it was unnecessary to further adjust the analysis for potential confounding variables.

Table 5.9. Unadjusted multivariable binary regression to identify the association between health behaviours in pregnancy & APGAR scores at five minutes of nine or less compared to 10 & seven to nine compared to 10

		p	Exp (B)	95% CI
9 or less vs 10	Smoking	.664	.75	.21, 2.71
	Alcohol	.882	1.06	.51, 2.19
	Exercise	.903	1.06	.40, 2.83
	Western	.590	.91	.63, 1.30
	Health conscious	.152	.77	.53, 1.10
7 to 9 vs 10	Smoking	.767	.82	.23, 2.97
	Alcohol	.721	1.14	.55, 2.40
	Exercise	.852	1.10	.41, 2.93
	Western	.671	.92	.64, 1.34
	Health conscious	.271	.81	.56, 1.18

5.3.3. Cognition & language development

Data on cognitive scores was available for 78 participants with a median score of 17.00 (IQR = 2.25). Receptive language scores were available for 62 participants with a median score of 11.00 (IQR = 2.00) and expressive language scores were available for 60 participants with a median of 13.00 (IQR = 2.00). See Figure 5.5 for score distribution.

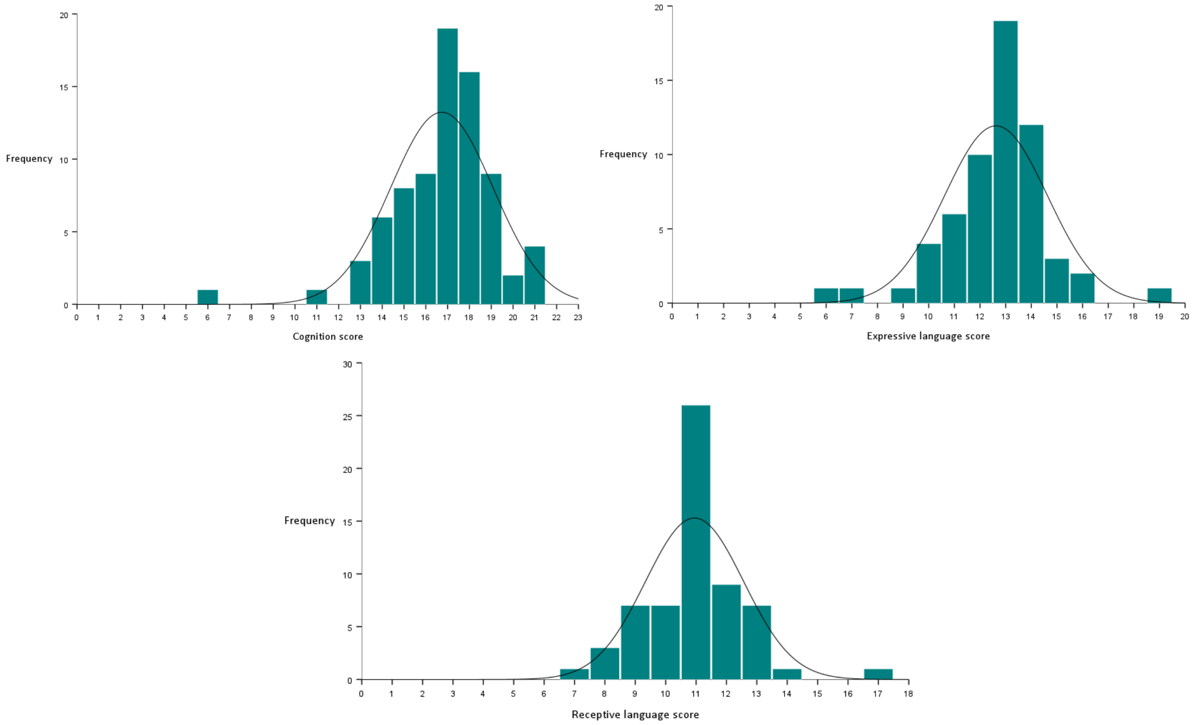


Figure 5.5 The distribution of cognitive, expressive language & receptive language scores on the Bayley Scales of Infant Development assessment

Linear regression was utilised to investigate the relationship between health behaviours and cognitive and language development (Table 5.10). At the unadjusted multivariable level, cognition F(5,71) = .58, *p* = .717, receptive language F(5,55) = 1.61, *p* = .048, expressive language F(5,53) = 1.74, *p* = .043, smoking during pregnancy was associated with receptive language and expressive language. When the analysis was adjusted for the potential confounders of parity and WIMD (Table 5.11) and after ensuring multicollinearity was not present, smoking at any point in pregnancy remained significant negatively associated with both receptive, F(7,53) = 1.12, *p* = .045, and expressive language, F(7,51) = 1.39, *p* = .231, reducing the scores by 2.83 and 4.03 respectively.

Table 5.10. Unadjusted multivariable linear regression assessing the association between health behaviours & cognition and language development

		p	B	95% CI
Cognition	Smoking	.485	-1.03	-3.94, 1.89
	Alcohol	.816	.13	-99, 1.26
	Exercise	.628	.31	-.97, 1.59
	Western	.647	-.17	-.90, .56
	Health Conscious	.185	-.41	-1.02, .20
Receptive language	Smoking	**.019**	-2.86	-5.22, -.50

	Alcohol	.115	.69	-.17, 1.54
	Exercise	.848	-.09	-1.04, .86
	Western	.916	.03	-.56, .62
	Health Conscious	.304	-.25	-.74, .24
Expressive language	Smoking	**.011**	-3.79	-6.69, -.89
	Alcohol	.352	.50	-.57, 1.57
	Exercise	.276	.65	-.54, 1.85
	Western	.656	.17	-.58, .91
	Health Conscious	.454	-.23	-.84, .38

Table 5.11 Adjusted multivariable linear regression assessing the association between health behaviours & cognition & language development scores

		p	B	95% CI
Receptive language	Smoking	**.025**	-2.83	-5.29, -.38
	Alcohol	.123	.69	-.19, 1.56
	Exercise	.842	.10	-.87, 1.07
	Western	.954	.02	-.61, .65
	Health Conscious	.339	-.25	-.76, .27
Expressive language	Smoking	**.009**	-4.03	-7.01, -1.04
	Alcohol	.296	.57	-.51, 1.66
	Exercise	.318	-.61	-1.82, .60
	Western	.757	.12	-.67, .91
	Health Conscious	.319	-.32	-.97, .32

5.3.4. Temperament

5.3.4.1. Contentiousness

A total of 115 participants were involved in this analysis. There was a median total CICS score of 7.00 (IQR = 4.00) (Figure 5.6).

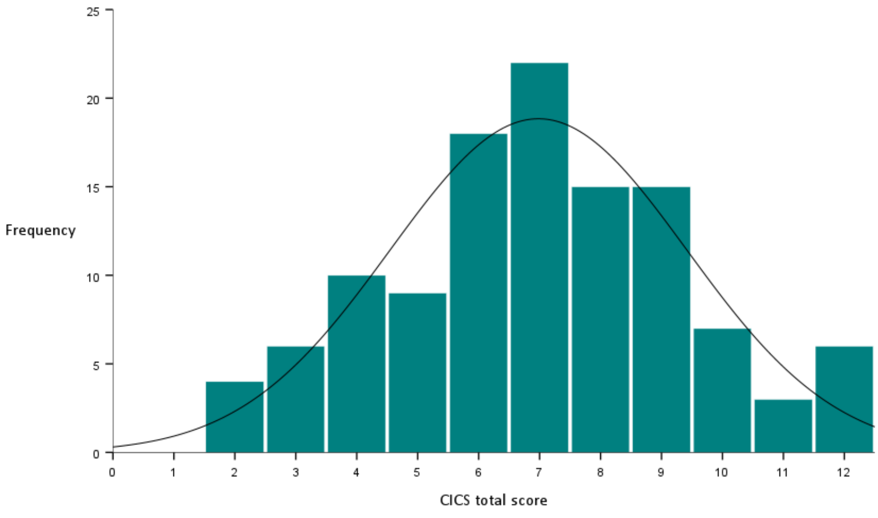


Figure 5.6. The distribution of total Cardiff Infant Contentiousness Scale scores

The association between health behaviours and infant contentiousness was investigated utilising linear regression (Table 5.12). At the unadjusted multivariable level, F(5,108) = .90, *p* = .042, a Health Conscious dietary pattern was associated with CICS score. This analysis was adjusted for the potential confounders of parity and WIMD score. Following adjustment and confirming multicollinearity was not present, multivariable linear regression, F(7,106) = 1.37, *p* = .226, identified that no health behaviours remained significantly associated with CICS score.

Table 5.12. Unadjusted & adjusted multivariable linear regression investigating the association between health behaviours in pregnancy & total CICS scores

		p	B	95% CI
Unadjusted	Smoking	.963	.05	-2.03, 2.13
	Alcohol	.970	-.02	-.95, .91
	Exercise	.863	-.10	-1.27, 1.07
	Western	.683	-.11	-.65, .42
	Health Conscious	**.041**	-.54	-1.07, -.02
Adjusted	Smoking	.975	.03	-2.06, 2.13
	Alcohol	.907	.05	-.87, .98
	Exercise	.968	.02	-1.14, 1.19
	Western	.465	-.20	-.73, .34
	Health Conscious	.085	-.46	-.98, .06

5.3.4.2. IBQ-R-SF

Linear regression was utilised to investigate the relationship between health behaviours and the major domains of infant temperament on the IBQ at Y1. When considering the three major domains of surgency F(5,101) = 1.32, *p* = .264, negativity F(5,101) = 2.08, *p* = .034 and regulatory capacity F(5,101) = 1.97, *p* = .089, unadjusted multivariable linear regression identified that only a Health Conscious dietary pattern was associated with the negativity domain (Table 5.13). This association remained when adjusting for the potential confounders of parity and WIMD score, F(7,99) = 1.98, *p* = .041. Indeed, a Health Conscious dietary pattern was significantly associated with negativity, with a one unit increase in Health Conscious dietary pattern score associated with a decrease in negativity score of .25.

Table 5.13. Unadjusted & adjusted multivariable linear regression assessing the association between health behaviours & major domains on the IBQ-R-SF

			p	B	95% CI
Unadjusted	Surgency	Smoking	.109	-.42	-.93, .10
		Alcohol	.195	-.16	-.39, .08
		Exercise	.530	.09	-.20, .39
		Western	.666	-.03	-.17, .11
		Health Conscious	.442	.05	-.08, .18
	Negativity	Smoking	.758	-.11	-.81, .59
		Alcohol	.933	-.01	-.34, .31

			p	B	95% CI
		Exercise	.569	-.12	-.52, .29
		Western	.386	-.08	-.27, .11
		Health Conscious	**.003**	-.27	-.46, -.09
	Regulatory	Smoking	.130	-.40	-.93, .12
		Alcohol	.114	-.20	-.44, .05
		Exercise	.326	.15	-.15, .46
		Western	.396	.06	-.08, .20
		Health Conscious	.068	.13	-.01, .26
Adjusted	Negativity	Smoking	.722	-.13	-.83, .58
		Alcohol	.968	.01	-.32, .33
		Exercise	.515	-.14	-.54, .27
		Western	.254	-.11	-.30, .08
		Health Conscious	**.008**	-.25	-.43, -.07

5.3.4.1. LabTAB tasks

5.3.4.1.1. Novel Toy task

Linear regression was used to assess the relationship between health behaviours and components of the Novel Toy task. At the unadjusted multivariable level (Table 5.14), intensity of facial fear $F(5,62) = 1.81$, $p = .038$, intensity of distress vocalisations $F(5,62) = 1.60$, $p = .173$, intensity of bodily fear $F(5,62) = 1.83$, $p = .042$, intensity of escape $F(5,62) = 1.26$, $p = .043$ and presence of startle response $F(5,62) = .57$, $p = .724$. Exercise was significantly positively associated with intensity of facial fear, whilst a Health Conscious dietary pattern was negatively associated with intensity of facial fear, bodily fear and escape.

Table 5.14. Unadjusted multivariable linear regression assessing the association between health behaviours & components of the Novel Toy task

		p	B	95% CI
Intensity of facial fear	Smoking	.569	.36	-.89, 1.61
	Alcohol	.412	-.21	-.71, .29
	Exercise	**.033**	.66	.06, 1.26
	Western	.955	-.01	-.35, .33
	Health Conscious	**.027**	-.31	-.59, -.04
Intensity of distress vocalisations	Smoking	.111	1.27	-.30, 2.84
	Alcohol	.245	-.37	-1.00, .26
	Exercise	.092	.65	-.11, 1.40
	Western	.906	-.03	-.46, .41
	Health Conscious	.116	-.28	-.63, .07
Intensity of bodily fear	Smoking	.241	.32	-.22, .86
	Alcohol	.389	-.10	-.31, .12
	Exercise	.103	.22	-.05, .48
	Western	.611	-.04	-.19, .11
	Health Conscious	**.020**	-.14	-.26, -.02
Intensity of escape	Smoking	.870	-.05	-.65, .55
	Alcohol	.689	-.05	-.29, .19
	Exercise	.180	.20	-.09, .49
	Western	.449	.06	-.10, .23
	Health Conscious	**.038**	-.14	-.28, -.01
Presence of startle response	Smoking	.734	-.01	-.06, .04

	Alcohol	.718	.00	-.03, .02
	Exercise	.221	-.02	-.04, .01
	Western	.864	.00	-.02, .01
	Health Conscious	.217	.01	.00, .02

The components of the Novel Toy task with significant associations in the unadjusted analysis were taken forward for analysis adjusted for the potential confounders of WIMD score and parity. At the adjusted level (Table 5.15), intensity of facial fear F(7,50) = 1.26, *p* = .041, intensity of bodily fear F(7,50) = 1.16, *p* = .047 and intensity of escape F(7,50) = .807, *p* = .586. A Health Conscious dietary pattern was no longer significantly associated with intensity of escape. However, exercise during pregnancy was significantly associated with increased intensity of facial fear score of .66. Also, a one unit increase in Health Conscious dietary pattern score was significantly associated with decreased intensity of facial fear score of -.31 and decreased intensity of bodily fear of -.15.

Table 5.15. Adjusted multivariable linear regression assessing the association between health behaviours & components of the Novel Toy task

		p	B	95% CI
Intensity of facial fear	Smoking	.560	.39	-.93, 1.71
	Alcohol	.420	-.21	-.72, .30
	Exercise	**.036**	.66	.05, 1.28
	Western	.938	-.01	-.38, .35
	Health Conscious	**.037**	-.31	-.60, -.02
Intensity of bodily fear	Smoking	.282	.31	-.26, .88
	Alcohol	.382	-.10	-.32, .12
	Exercise	.124	.21	-.06, .48
	Western	.719	-.03	-.19, .13
	Health Conscious	**.023**	-.15	-.27, -.02
Intensity of escape	Smoking	.980	.01	-.63, .64
	Alcohol	.695	-.05	-.29, .20
	Exercise	.169	.21	-.10, .50
	Western	.535	.05	-.12, .23
	Health Conscious	.064	-.13	-.27, .01

5.3.4.1.2. Sustained Attention task

To investigate the association between health behaviours and components of the Sustained Attention task, linear regression was employed. At the unadjusted multivariable level (Table 5.16), positive affect F(5,62) = .21, *p* = .959, negative affect F(5,64) = 1.03, *p* = .411, there was no significant associations present, as such adjustment for potential confounders was not undertaken.

Table 5.16. Unadjusted multivariable linear regression assessing the association between health behaviours & components of the Sustained Attention task

		p	B	95% CI
Positive affect	Smoking	.931	-.02	-.58, .53
	Alcohol	.589	.06	-.17, .29
	Exercise	.419	-.10	-.35, .15
	Western	.827	-.02	-.16, .13
	Health Conscious	.725	.02	-.10, .14
Negative affect	Smoking	.878	-.06	-.79, .68
	Alcohol	.858	-.03	-.32, .27
	Exercise	.529	.10	-.22, .43
	Western	.103	-.16	-.35, .03
	Health Conscious	.190	-.10	-.26, .05

5.3.4.1.3. Maternal Separation task

Linear regression was utilised to assess the association between health behaviours and components of the Maternal Separation task. At the unadjusted multivariable level (Table 5.17), intensity of facial fear $F(5,45) = .61$, $p = .694$, intensity of distress $F(5,65) = .68$, $p = .639$, latency to fear response $F(5,65) = 1.02$, $p = .415$, intensity of bodily fear $F(5,57) = .47$, $p = .797$ and intensity of escape response $F(5,65) = .94$, $p = .463$. There were no significant associations between health behaviours and any of the components. As such, adjustment for confounders was not necessary.

Table 5.17. Unadjusted multivariable linear regression assessing the association between health behaviours & components of the Maternal Separation task

		p	B	95% CI
Intensity of facial fear	Smoking	.275	.72	-.59, 2.03
	Alcohol	.639	.12	-.39, .63
	Exercise	.592	-.16	-.74, .42
	Western	.673	.07	-.24, .37
	Health Conscious	.586	.08	-.23, .39
Intensity of distress	Smoking	.951	.07	-2.02, 2.15
	Alcohol	.231	.50	-.33, 1.33
	Exercise	.405	-.40	-1.35, .55
	Western	.738	.09	-.45, .63
	Health Conscious	.379	-.21	-.68, .26
Latency to fear response	Smoking	.573	-8.25	-37.35, 20.86
	Alcohol	.081	-10.28	-21.86, 1.30
	Exercise	.322	-6.63	-19.91, 6.64
	Western	.525	2.41	-5.12, 9.95
	Health Conscious	.833	.70	-5.89, 7.28
Intensity of bodily fear	Smoking	.835	-.08	-.85, .69
	Alcohol	.141	.24	-.08, .57
	Exercise	.756	-.06	-.42, .31
	Western	.760	.03	-.18, .25
	Health Conscious	.865	-.02	-.20, .17
Intensity of escape response	Smoking	.096	-1.06	-2.31, .20
	Alcohol	.438	.20	-.30, .70

	Exercise	.283	-.31	-.88, .26
	Western	.975	-.01	-.33, .32
	Health Conscious	.490	-.10	-.38, .19

5.3.4.2. CBQ

Data on the CBQ-SF was available for 115 participants. Multivariable linear regression was utilised to investigate the association between health behaviours in pregnancy and the three major domains on the CBQ-SF at Y4 (Table 5.18). At the unadjusted multivariable level, surgency/extraversion $F(5,106) = 1.93$, $p = .095$, negative affectivity $F(5,106) = .578$, $p = .717$ and effortful control $F(5,106) = .54$, $p = .744$. No health behaviours were significantly associated with any major domain of temperament. As such, no further analysis was conducted.

Table 5.18. Unadjusted multivariable linear regression assessing the association between health behaviours & major domains on the CBQ-SF

		p	B	95% CI
Surgency/Extraversion	Smoking	.154	.53	-.20, 1.26
	Alcohol	.221	-.17	-.44, .10
	Exercise	.642	.08	-.26, .42
	Western	.053	.15	.00, .30
	Health Conscious	.093	.13	-.02, .28
Negative affectivity	Smoking	.467	.237	-.41, .88
	Alcohol	.820	.03	-.21, .27
	Exercise	.310	-.16	-.46, .15
	Western	.437	.05	-.08, .18
	Health Conscious	.923	.01	-.13, .14
Effortful control	Smoking	.321	-.34	-1.02, .34
	Alcohol	.614	.06	-.19, .31
	Exercise	.498	.12	-.21, .42
	Western	.516	-.05	-.18, .09
	Health Conscious	.901	.01	-.13, .15

5.4. Discussion

5.4.1. Summary

This chapter aimed to address Aim three of the thesis, by investigating the influence of maternal health behaviours in pregnancy on short and longer term infant outcomes. Overall, the findings within this support the proposed hypotheses that healthy prenatal behaviours are associated with positive maternal and infant outcomes, and unhealthy behaviours are associated with negative or suboptimal outcomes. An outline of the main findings regarding the effect of prenatal maternal health behaviours are provided below.

- Prenatal smoking was associated with decreased overall CBWC, whilst undertaking prenatal exercise and a Health Conscious dietary pattern were associated with increased overall CBWC and birthweight (kg).
- A Health Conscious dietary pattern in pregnancy was associated with decreased likelihood of an infant being born SGA, whilst prenatal alcohol consumption was associated with decreased likelihood of an infant being born LGA.
- Prenatal maternal health behaviours were not associated with APGAR scores.
- Prenatal smoking was associated with decreased language development in one year old infants.
- A Health Conscious dietary pattern in pregnancy was associated with decreased negative temperament, whilst prenatal exercise was associated with an increased negative temperamental response at one year of age.

5.4.2. Birthweight outcomes

Traditionally, the birthweight of infants has been measured utilising population based classifications. However, the use of CBWC is now recommended due to the associated advantages, such as being able to more accurately identify if infants are pathologically rather than physiologically small (Gardosi et al., 2009). Despite this, CBWC are still rarely incorporated in research. The current research utilised both these measurement systems and identified that 2.60% of infants were classified LBW compared to 7.40% classified as SGA, whilst 18.30% were considered HBW compared to 14.10% as LGA. This suggests that the use of traditional measures classifies too many infants as high in weight and too few as low in weight, leading to the possibility of some infants not receiving appropriate levels of medical care. This data supports the argument that CBWC are more accurate in identifying infants that are potentially at risk for complications.

Regarding the influence of prenatal health behaviours, undertaking exercise and a Health Conscious dietary pattern in pregnancy were associated with increased overall CBWC, whilst smoking in pregnancy was associated with decreased CBWC. Conversely, when considering traditional birthweight measures, only a Health Conscious dietary pattern in pregnancy was associated with increased birthweight. Additionally, a Health Conscious dietary pattern was associated with decreased likelihood of giving birth to an SGA infant, whilst consuming alcohol in pregnancy was associated with decreased likelihood of giving birth to an LGA infant. It is important to note that this LGA finding isn’t positive. Instead, it suggests that alcohol impacts on the growth of the infant, perhaps through interfering with the availability of nutrients. As such, whilst alcohol is associated with reduced LGA births it certainly isn’t an association to be encouraged. Additionally, the difference in findings between CBWC and traditional birthweight measures highlights that the impact of health behaviours may previously have been underestimated by studies neglecting to incorporate CBWC.

The health behaviour most consistently associated with birthweight outcomes in this thesis was a Health Conscious dietary pattern, which was associated with increased overall CBWC and traditional birthweight (kg) as well as the reduced likelihood of being born SGA. No influence of an unhealthy Western dietary pattern was identified. It is difficult to compare these findings to previous research, due to the inconsistent conclusions and frequent failure to utilise CBWC, as discussed in Chapter One. Studies vary between identifying an association and determining that there was no effect. In support of our findings, studies such as Saunders et al. (2014) and Ancira-Moreno et al. (2020) also identified no influence of a prenatal Western dietary pattern on birthweight outcomes. Only Knudsen (2008) reached a different conclusion, with a Western dietary pattern increasing the risk of SGA deliveries. Given that these studies do not utilise CBWC, the current research enhances our understanding in this area. Regarding the Health Conscious dietary pattern findings, this is also supported by previous research. Studies that utilised only minimally customised measures, such as that by Thompson et al. (2010) in New Zealand and Timmermans et al. (2012) in Rotterdam identified that healthier dietary patterns were associated with reduced negative birth outcomes such as SGA infants. Additionally, comprehensive reviews have identified that healthier dietary patterns are associated with higher overall birthweight and reduced LBW or SGA risk (Abdollahi et al., 2021, Gete et al., 2020, Biagi et al., 2019). However, it is crucial to note that these reviews emphasise the heterogeneity and low quality of the evidence in this area. The only directly comparable research in the area was that by Englund-Ögge (2014). Like the current study, this research utilised near fully customised centiles and also identified that healthier dietary patterns were associated with improved birthweight outcomes. The incorporation of CBWC is a strength of this current research, the use of which ensures that this research enhances the weak evidence in this area.

Our finding that smoking is related to an overall reduction in CBWC is in line with the general trend in the literature. Indeed, this research enhances the understanding gained from the two previous studies conducted in Wales (Johnson et al., 2017, Meis et al., 1997).

These studies also identified a negative influence of smoking on birthweight classifications. However, this research only utilised traditional birthweight measures that were not even customised for gestational age and did not consider the influence of any other health behaviours. Thus, the current research improves the evidence base in Wales. Reassuringly, the only other study identified that utilised near fully customised birthweight centiles also found that smoking influenced and reduced birthweight outcomes (McGowan and McAuliffe, 2013). As such, our finding of an influence of prenatal smoking is compelling.

The evidence indicating that prenatal alcohol consumption reduced the likelihood of delivering an LGA infant was perhaps surprising. Nevertheless, although no previous studies have identified this specific association, others have determined alcohol consumption does indeed reduce overall birthweight. For example, a large study conducted in the UK with 1303 participants utilising fully customised birthweight centiles, a major strength of the study, also identified that alcohol consumption reduced overall CBWC (Nykjaer et al., 2014). Moreover, a strong study by Strandberg-Larsen et al. (2017) utilised a pooled meta-analysis of data from nine European birth cohorts, and identified that alcohol consumption was linked to lower birthweight. Whilst this study didn't utilise customised measures, both this and particularly Nykjaer et al. (2014) provide convincing support for the current findings. There has, however, been research conducted that draws differing conclusions. For example, McCarthy et al. (2013) utilised data from the multinational SCOPE cohort and found no association between any level of alcohol consumption and birthweight outcomes. Moreover, a review by Pereira et al. (2019) determined that overall there was no compelling evidence of an effect. Indeed, it is true that in the current research, alcohol consumption was only associated with the LGA outcome and no others, thus perhaps the influence of alcohol is limited. However, as with many other areas, there is has been a high level of heterogeneity between studies which may have influenced reviews such as that by Pereira et al. (2019). Moreover, again studies rarely use CBWC or consider multiple health behaviours, all factors which could explain the difference in findings. In light of this apparent inconsistency and given that the current findings are supported by compelling evidence, this research improves the knowledge base for the influence of alcohol.

In this chapter it was also identified that exercise in pregnancy was associated with increased overall CBWC. Given that there was no simultaneous influence on classifications of SGA, AGA or LGA, it suggests that this overall increase in CBWC was within healthy levels, thus had a positive influence. Previous evidence, a mixture of both randomised control trial (RCT) and observational studies, has also identified that overall prenatal exercise had either no effect (Vargas-Terrones et al., 2019a) or a positive influence by reducing HBW or LGA outcomes (Davenport et al., 2018b, Wiebe et al., 2015). Thus, this supports our finding. Indeed, the current research also supports that identified in the only previous study conducted in Wales in this area. Morgan et al. (2014), also discussed shortly in relation to APGAR scores, found no association between physical activity levels as measured by an accelerometer and the risk of SGA or LGA deliveries. It is reassuring that the studies conducted in Wales reached similar conclusions. Moreover, the current research enhancing the findings of Morgan et al. (2014) by utilising CBWC, taking a view of exercise across pregnancy and considering the simultaneous influence of multiple health behaviours.

Overall, our findings that positive health behaviours were associated with improved birthweight outcomes and negative behaviours such as smoking were associated with poorer outcomes is supported by the literature. However, the current research enhances the existing understanding, especially in Wales, through the use of CBWC and consideration of multiple health behaviours.

5.4.3. APGAR

APGAR scores are an important indicator of the health status of newborn infants. Typically scores above seven are considered ‘normal’, although research has recently begun to consider the advantages of studying scores in the low ‘normal’ range. In the GiW cohort, it was identified that the median APGAR scores at one and five minutes were nine and 10 respectively, with very few infants scoring below the ‘normal’ range. Indeed, 98.10% scored within the ‘normal’ range at one minute, and 99.40% at five minutes, similar to the 98% at five minutes identified in the most recent Welsh Government data (Welsh Government, 2021). This indicates that the infants born within the cohort can overall be considered healthy at birth. It is possible that this small range of APGAR scores was inevitable given the cohort characteristics. Indeed, that the mode of delivery was predominantly, although not exclusively, ELCS may have resulted in the high scores, as low APGAR scores are often a reflection of difficulties caused by the birthing process, such as prolonged labour and asphyxiation or use of instruments. These difficulties are unlikely to occur in a planned elective caesarean section (ELCS). Nevertheless, it is reassuring that the prevalence obtained within this analysis was similar to that in the Welsh Government data, suggesting the influence of this cohort characteristic is minimal.

Additionally, no associations were identified between maternal health behaviours in pregnancy and APGAR score, overall, low or low 'normal' compared to high, at either one or five minutes. This could indicate that health behaviours have no impact on APGAR scores. However, it is also possible that no effect was identified due to the nature of the cohort. Recruitment focused on relatively healthy participants without serious complications or recorded fetal anomalies, which could have contributed to the reassuringly high APGAR scores that had only little range. Consequently, there may have been too little range to identify an effect of health behaviours.

Nevertheless, our finding of a lack of effect of health behaviours is supported by the previous, albeit limited, research in this area. Although occasionally studies identified a health behaviour effect, such as that by Abdallah et al. (2021) who found an association between smoking and lower APGAR scores at one minute, this typically disappears after adjustment for confounders. Similar to the current findings, the overall trend in the limited literature is one of no effect. For example, the only previous study examining dietary patterns also identified no association between unhealthy or healthy dietary patterns and APGAR scores at five minutes (Mikeš et al., 2021). Whilst in support of our findings, this appears to be an emerging area of research and thus further evidence is required in a range of populations to confirm this lack of association. Furthermore, this lack of effect is supported by studies such as James et al. (1995), who found no influence of prenatal alcohol in an early study in Bristol, and a review by Odintsova et al. (2019) that concluded that overall prenatal smoking had no effect. Moreover, in the only previous study on this topic in Wales, neither high nor low levels of physical activity as measured by an accelerometer were associated with low APGAR scores at five minutes (Morgan et al., 2014). Not only is this in support of the current findings, but current research expands on this study by taking a broader examination of overall and categories of APGAR scores and considering a range of health behaviours. Moreover, the current research measures exercise by taking a view across pregnancy rather than one specific timepoint. It is extremely reassuring that these two studies on Welsh populations reach similar conclusions. It is also noteworthy that no previous research has examined the effect of prenatal health behaviours on APGAR scores in the low 'normal' range, thus no comparisons can be made here. Consequently, overall the research within this thesis contributes to and enhances our understanding of the influence of prenatal health behaviours on APGAR scores.

5.4.4. Neurodevelopment

Neurodevelopment begins in pregnancy and has been argued to be one of the most important processes to occur in the first 1000 days (Niño Cruz et al., 2018). Whilst research has been undertaken to examine the influence of health behaviours in this area, the topic suffers greatly from heterogeneity, with inconsistent findings focusing on a range of ages. The research within this thesis sought to enhance the evidence in this area and determined that whilst no maternal health behaviours in pregnancy were associated with cognitive development at age one, smoking in pregnancy was associated with decreased language development.

Our finding of a negative influence of smoking on language development at one year of age is supported by evidence identified that focused on the same age. Indeed, both Polańska et al. (2015) in Poland and Hernández-Martínez et al. (2017) in Spain found that prenatal smoking was associated with poorer language development at 12 months. This differs to the studies that determined smoking had no effect on language (Donald et al., 2019, Koutra et al., 2012), but focused on infants of older ages, specifically 18 months and two years. In light of this, it may be possible that prenatal smoking causes a deficit in language development in early infancy, however this effect may be neutralised as the child grows older. On the other hand, Koutra et al. (2012) and Donald et al. (2019) also identified no influence of prenatal smoking on cognitive outcomes, which is in support of our findings, whereas Polańska et al. (2015) and Hernández-Martínez et al. (2017) determined that prenatal smoking had a negative impact. Clearly, there is a high level of inconsistency within this research area. It is possible that this may be due to differences in prenatal smoking timepoints or perhaps measures of neurodevelopment. Nevertheless, no previous research has investigated this in the UK or indeed Wales, and so the current work helps to develop the research picture within this area.

Additionally, our finding of no influence of prenatal alcohol consumption on neurocognitive outcomes at one year of age, in a cohort where heavy drinking is rare, is also supported by the existing literature. Indeed, whilst some research such as that by McCormack et al. (2018) determined prenatal alcohol was positively associated with outcomes, overwhelming the literature demonstrates no association. For example, Halliday et al. (2017) and Polańska et al. (2015), the latter previously mentioned in relation to smoking, identified that there was no association between prenatal alcohol consumption and cognitive or language outcomes up to two years of age. Moreover, Williams Brown et al. (2010) reported a possible dose response, although the overall relationship was not significant. This could be a possible route to investigate in the GiW cohort in the future. Overall, our findings on alcohol provide further support and understanding of the influence on neurocognitive outcomes. Regarding dietary patterns, the current research found no influence on neurocognitive outcomes. Unfortunately, it is difficult to consider our findings on dietary patterns in the context of existing research, as there has been no research investigating the influence of this factor on the outcomes of interest. Whilst a review by Borge (2017) identified that improved diet quality was associated with improved cognitive outcomes, this was not investigated in our age of interest and diet quality differs to our health behaviour. As such, whilst no firm conclusions can currently be formed, the current research forms the basis upon which to further develop the evidence on the influence of dietary patterns.

The current research also identified no effect of prenatal exercise on cognitive or language outcomes at 12 months. This supported the findings of previous research such as that by Davenport et al. (2018b), which concluded in a review that there was no association between exercise and cognitive outcomes. Similarly, reviews by Niño Cruz et al. (2018) and Álvarez-Bueno et al. (2018) also reached this conclusion. As such, our findings contribute to and strengthen the literature within this area, particularly as no research has investigated cognitive outcomes at this age in the UK. Unlike the current research, other studies have however determined that prenatal exercise influences language development. This was identified by the reviews previously highlighted in relation to cognition (Niño Cruz et al., 2018, Álvarez-Bueno et al., 2018) and by the only study conducted in this area in the UK (Jukic et al., 2013). This difference in findings could again be explained by the severe heterogeneity that has been noted within this area. Studies vary in sample size, measures and timepoints of data collection. Indeed, the studies that identified an association contained a range of ages and did not specifically focus on our age of interest. Consequently, it is entirely possible that the influence of prenatal exercise does not become apparent until the infant is of an older age. Additional future data collection within the GiW cohort could be considered to investigate this possibility. Furthermore, the current evidence may differ to some existing findings as it is unique in that it considered the influence of multiple health behaviours simultaneously, which may have actually provided more accurate findings.

Overall, the current research regarding the influence of prenatal health behaviours on neurocognitive outcomes at one year of age enhances the existing understanding of this area and provides the first evidence of this in Wales.

5.4.5. Temperament

Early temperament is believed to form the basis of later personality and behaviour development (Gartstein and Skinner, 2018). The current work examined both subjective and objective measures of early temperament. It was identified that overall, a prenatal Health Conscious dietary pattern was associated with decreased infant negativity on both subjective and objective measures, and prenatal exercise was associated with increased negative response on one objective measure. Given the overall paucity of research within this area, the current findings improve the understanding of how prenatal health behaviours can influence early temperament.

There is not a vast literature base on the influence of prenatal health behaviours on early temperament outcomes and the research that does exist differs in findings at times. It is rare for studies to utilise both subjective and objective measures of temperament, and it is a strength of these findings that the positive influence of a Health Conscious dietary pattern was identified in both. This finding is supported by the only previous study that has investigated this area. Schoeps et al. (2022), in the Growing Up in New Zealand cohort, also determined that healthier dietary patterns were associated with decreased overall infant negativity. Additionally, no association was found between prenatal smoking or alcohol consumption and infant temperament. This is dissimilar to the overall trend in the research that indicates prenatal smoking and alcohol consumption to be associated with increased infant negativity (Froggatt et al., 2020, Bakhireva et al., 2018). It is possible that the differences in findings are due the consideration of multiple health behaviours simultaneously in this research, or due to the heterogeneity between studies in the measures utilised to assess temperament and the age of assessment. Finally, that no association between prenatal health behaviours and additional outcomes such as surgency and regulatory capacity was identified, is in line with the limited previous research (Mundy, 2009, Schoeps et al., 2022, Bakhireva et al., 2018).

The finding that prenatal exercise was associated with increased negative responses is perhaps surprising. The only previous similar study in this area, Schoeps et al. (2022), determined an opposite association albeit with a focus on pre-pregnancy exercise. It should be noted however, that this finding was only identified on one component of one measure out of the many that were utilised to investigate temperament. As such, it may be that this finding is spurious. This raises a possible issue of multiple comparisons. This topic, and the reasons for not undertaking corrections for multiple comparisons throughout the thesis, are discussed at length in Chapter Two. However, in light of the measures utilised to assess this specific outcome, confidence in this particular finding might be strengthened by investigating any potential influence of multiple comparisons in the future.

No associations were identified between prenatal health behaviours and child temperament as measured on the CBQ. Very little previous research was identified that examined the influence of prenatal behaviours on this particular age group. Only the research by Martin et al. (2006) examined this in the context of smoking and determined that prenatal smoking was associated with increased likelihood of negative affect at five years of age. As such, it is difficult to place the current findings in the context of previous literature. Given the findings of no influence at four years but an effect at 12 months, it may suggest that prenatal health behaviours only have a short-term influence on temperament outcomes. It is also possible that this absence of an association is due to inherent issues with the CBQ domain classification. Indeed, there has been discussion in the literature questioning if the three major domains accurately reflect the patterns within the data (Lipska et al.). Despite this, these domains are frequently utilised in research as they allow for direct comparisons to be made with data collected in the IBQ. Nevertheless, it may enhance the current findings to investigate the effect of prenatal health behaviours on the subdomains of this measure in the future.

It is also important to note that there are limitations relating to the analyses conducted utilising both the Y1 and Y4 timepoints, relevant to both the temperament and neurodevelopment analyses. Due to issues with participant retention, the sample size of these timepoints is significantly smaller than that at the A1 timepoint. These smaller sample sizes could be limiting results, as it is possible that different findings might have been obtained within a larger sample. It also may limit results as the sample size resulted in the inclusion of only a small number of confounders, to avoid over-fitting the models. As such, it was not possible to include many terms that may have been important in the adjusted analyses. Reassuringly, however, the sample size within these timepoints is similar to many studies that investigate infant outcomes and we were able to obtain findings that were complimentary to previous research where it was available.

In summary, there has been only limited research interest in the influence of prenatal health behaviours on early temperament outcomes, especially in relation to exercise and dietary patterns. The current research begins to address the gap in the current understanding in this area.

5.4.6. Conclusions

As highlighted throughout this thesis, the existing literature in this area is frequently inconsistent, does not consider the influence of multiple health behaviours simultaneously and extremely rarely is conducted in Wales. Although direct causality has not been determined (addressed previously in Chapter Two), here it has been identified that not only do prenatal health behaviours influence maternal outcomes, as discussed previously in Chapter Four, but they also have an effect on short and longer term infant outcomes. Indeed, the evidence supports the proposed hypotheses that healthy prenatal behaviours are associated with positive improve outcomes, and unhealthy behaviours with suboptimal outcomes. Thus, this research enhances and addresses the gaps in the existing literature and provides improved understanding regarding the influence of prenatal health behaviours in Wales.

Chapter 6 - Discussion

6.1. Discussion

6.1.1. Summary

Pregnancy, fundamentally, is the important process required to produce the next generation. Events and exposures in pregnancy, as well as genetic factors, can influence future lifelong health and development in both mother and child. Of particular importance are a woman's health behaviours which, unlike other influences on the pregnancy environment, are potentially modifiable in nature. Despite the critical importance of pregnancy for human health, pregnancy as a whole is a severely under-funded area of research. This lack of attention becomes particularly evident when considering the influence of prenatal health behaviours on maternal and infant outcomes. The existing research in this broad area is often limited and conclusions are mixed and inconsistent. Research rarely considers the influence of multiple health behaviours despite their co-occurring nature. Moreover, there is a severe lack of research investigating this area specifically in Wales, a crucial oversight given the differences between Wales and other UK nations. This thesis attempts to address this gap in the literature and offer evidence that can improve the knowledge base, providing a basis to further improve outcomes.

Given that much of this research was the first to be undertaken in Wales, it is important that the Grown in Wales (GiW) cohort is representative of the general population. As previously discussed in Chapter Two, there were only very minimal differences between the GiW cohort participants and all women who gave birth at the University Hospital of Wales (UHW) during the same period (N = 7600) (Janssen et al., 2018). Additionally, the cohort demographics are similar to another study that took place in South Wales, that was worked upon during this PhD (Savory et al., 2021), as well as other large UK based cohort studies such as the Avon Longitudinal Study of Parents and Children (ALSPAC) (Northstone et al., 2007). Finally, a large number of publications have resulted from the GiW cohort, with findings and conclusions that are similar to existing research with a range of different participant populations. Thus, this supports that the GiW cohort is representative in nature.

The thesis first investigated the health behaviours that occur during pregnancy in a Welsh population, thus addressing the first research question: What are the health behaviours undertaken in pregnancy by women in Wales? Overall, 11% of participants smoked and 38.20% consumed alcohol during pregnancy. A discrepancy between behaviours reported in the questionnaire and midwife recorded notes was also highlighted, indicating that routinely collected data in hospital notes may underestimate these behaviours. Regarding exercise, only

16.60% of women reported undertaking exercise during pregnancy, defined as 30 minutes or more at least once a week, whilst two prenatal dietary patterns were identified from the food frequency questionnaire (FFQ); Western and Health Conscious. This data has not previously been collected in Welsh Government maternity reports. The factors influencing these health behaviours were also investigated.

Following the identification of the prenatal health behaviours within the GiW cohort, it was possible to address research question two: what is the influence of the maternal health behaviours in pregnancy on maternal and infant outcomes in Wales? When considering the influence of prenatal health behaviours simultaneously; a Health Conscious dietary pattern and exercise were associated with improved breastfeeding and mother-infant bonding outcomes respectively, whilst alcohol consumption, a Western dietary pattern and smoking were associated with an increased likelihood of suboptimal gestational weight gain (GWG), maternal mental health and mother-child relationship outcomes. Similarly, in the infant, a Health Conscious dietary pattern was associated with improved birthweight and temperament outcomes, whilst smoking and alcohol consumption were associated with an increased likelihood of suboptimal birthweight outcomes as well as language development in the case of smoking. Thus overall, the research within the PhD supported the proposed hypotheses that healthy prenatal health behaviours are associated with positive maternal and infant outcomes, whilst unhealthy prenatal health behaviours are associated with negative or suboptimal maternal and infant outcomes.

6.1.2. Implications

This research provides an understanding of the nature of maternal prenatal health behaviours in Wales and the impact these have on various maternal and infant outcomes. Not only does this begin to address a lack of research in Wales, but this additional knowledge could have further implications. Unlike other factors such as sociodemographic and biological variables, health behaviours are potentially modifiable. This improved knowledge of health behaviours could provide the basis for interventions or strategies to change and optimise these five behaviours which, given the influence on maternal and infant outcomes, could have long reaching implications. Regarding this potential behaviour change, evidence has indicated that women are keen to change and improve their health behaviours in pregnancy, however it is imperative that an atmosphere of blame for suboptimal behaviours is not created. It is also well established that motivation alone is not sufficient for behavioural change. For example, the COM-B model proposes that capability, opportunity as well as motivation is vital for change (Michie et al., 2011). As such, the current research could enable women to be provided with the encouragement, knowledge, skills and support required to enable the choice of healthier prenatal behaviours.

As with all research it is important for it to be communicated effectively in order to reach its full potential. In light of this, a number of publications have already resulted from this PhD, with further publications planned in the immediate future. This research has been presented at a range of health-related academic conferences. Moreover, the work of this thesis recently received an Audrey Jones Award for research conducted by women in Wales. As a direct result, this research has been presented to the Wales Assembly of Women, a group of women with the ambition to enable change for and improve conditions related to the life of women in Wales. As a further consequence of this, the findings have been shared with and communicated to women working within the Welsh Government who have the potential to implement change: the Minister for Health and Social Services; the Deputy Minister for Social Services; the Deputy Minister for Mental Health and Wellbeing and finally the Minister for Social Justice. Thus, this thesis has the potential to improve the understanding of the prenatal health behaviours of women in Wales.

6.1.3. Future directions

Due to the range of topics incorporated within this thesis, there is great potential for further research to be developed that goes beyond the scope of this thesis. Indeed, rather than considering the influence of each health behaviour within the multivariable models, it may be possible to investigate the incorporation of overall health behaviour scores. For example, Navarro et al. (2020) combined data on smoking, alcohol, exercise and body mass index (BMI) into a lifestyle score, which was then utilised to investigate infant outcomes and childhood obesity. Now that this thesis has provided an understanding of the influence of each health behaviour within the cohort, it may be possible to expand this research to compute an overall health behaviour score for each participant. This would enable further investigation of overall healthy behaviour (i.e. high scores) compared to unhealthy behaviour (i.e. low scores). Additionally, to date there have been five waves of data collection, most recently when the infants reached four years of age. With funding, it would be interesting to continue the collection of data now that the children are reaching seven years of age. This would enable the investigation of any continuing influence of maternal health behaviours in pregnancy on child development and outcomes.

The cohort contains a wealth of data that was not possible to incorporate within this thesis. This includes the Child Behaviour Checklist, as outlined in Chapter Two. It would be exciting to investigate the influence of maternal health behaviours in pregnancy on scores within this checklist, such as that pertaining to attention deficit hyperactive disorder. It may also be interesting to investigate further maternal outcomes, such as postpartum weight retention, which would follow on well from the gestational weight gain analyses. This data on weight is readily available within the cohort and would be a valuable area to investigate given that postpartum weight retention is associated with many poor long term outcomes. Furthermore, there is a range of biological data that has not been included. For example, given the influence of prenatal exercise on the mother-child relationship, there is potential to explore the mechanism behind this and consider whether factors such as human placental lactogen mediate this relationship. Additionally, due to the extensive work of the previous members in PregLab, there is placental gene expression for participants that could be explored as potential mechanisms. Finally, the post-doctoral position that will be undertaken upon the conclusion of this PhD will be exploring this overall topic further, with a focus on investigating the influence of free fatty acids on maternal mental health and child developmental outcomes.

6.1.4. Final conclusions

Prenatal maternal health behaviours are an important modifiable environmental influence in pregnancy, however, it is often an under-researched area. This thesis sought to address the gaps in the literature, with a particular focus on the paucity of research on Welsh populations. This research has provided insight into the prenatal maternal health behaviours in a Welsh population as well as the influence of these behaviours on important short and longer term maternal and infant outcomes. Not only are these outcomes important in themselves, they are also linked to further health and developmental outcomes. The understanding the research of this PhD offers may provide the basis for behavioural targets for future interventions and support strategies to improve and promote positive maternal prenatal health behaviours and thus pregnancy and longer term maternal and infant outcomes in Wales.

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Appendices

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Study ID.............

Year Four Questionnaire

Title of Project: The Grown in Wales Study

Version 1.1

23/01/2020

Thank you for agreeing to answer these questions. It would help us if you could answer all the questions. However, if you feel unhappy about answering any of them, leave them blank. Unless otherwise stated, the questions will refer to your pregnancy/child born in 2015/2016 who took part in the Grown in Wales study (your 'GiW' baby).

Today's date ....

Questionnaire Part 1: About you

- **What is <u>your</u> age?** ....
- **What is your current weight?** ....kg *OR* ....st............lbs
- **What is your height?** ....cm *OR* ....ft............inches
- **What is your current postcode?** ....
- **Are you currently working?**

  Yes ☐ No ☐ Do not wish to say ☐

  If yes:

  On average how many hours do you work per week? ....

  What is your occupation? ....

- **What is your annual family income before deductions?**

  <£18,000 ☐ £18,000-£25,000 ☐ £25,001-£43,000 ☐

  >£43,000 ☐ Do not wish to say ☐

- **What is your highest level of education?**

  Left before GCSE ☐ GCSE/O Levels ☐ A Levels ☐

  University ☐ Postgraduate ☐ Vocational Training ☐

  Do not wish to say ☐

- **What is your current marital status?**

  Married ☐ Separated ☐ In a relationship ☐ Widowed ☐

  Divorced ☐ Single ☐ Do not wish to say ☐

- **Are you currently smoking?**

  Yes ☐ No ☐ E-cigarettes/Nicotine gum or patches ☐

  Do not wish to say ☐

  If yes please estimate the number per day ……………..

- **Do you currently drink alcohol?**

  Yes, almost every day ☐ Yes, once or twice a week ☐

  Yes, once or twice a month ☐ Yes, once every couple of months ☐

  No, never ☐ Do not wish to say ☐

- **Do you currently undertake strenuous exercise?**

  Yes ☐ No ☐ Do not wish to say ☐

  If yes, please write the types of exercise & how often per week

  ………………………………………………………………………………………

- **Have you had any other children since your 'GiW' baby?**

  Yes ☐ No ☐ Do not wish to say ☐

  If yes, please write down their birth date(s)

  ………………………………………………………………………………………

- **During your 'GiW' pregnancy did you take any supplements? *e.g. folic acid, omega 3, vitamin C***

  Yes ☐ No ☐ Don't know ☐ Do not wish to say ☐

  If yes, please specify…………………………………………………………………………………………

- **Was your 'GiW' pregnancy planned?**

  Yes ☐ No ☐ Don't know ☐ Do not wish to say ☐

- **Have you experienced any physical health problems since the birth of your 'GiW' child?**

  Yes ☐ No ☐ Do not wish to say ☐

  If yes, please specify and for how long……………………………………………………

- **Since the birth of your 'GiW' child, have you suffered from any mental health problems? (e.g. depression, anxiety)**

  Yes ☐ No ☐ Do not wish to say ☐

  If yes:

  Which mental health problem? ……………………………………………………………

  When was this first diagnosed? ……………………………………………………………

  Were you prescribed medication? Yes ☐ No ☐

  If yes please specify which medication and how long it was taken for

  ………………………………………………………………………………………………

- **Have you suffered from any mental health problems in later pregnancies?**

  Yes ☐ No ☐ Do not wish to say ☐

  If yes, please specify ……………………………………………………………………………………

Please turn over for the next set of questions

DIRECTIONS: In the **last month**, how often did you eat the following foods? For each food type, please tick one box that best describes how often you ate this food

	More than once/day	Once/day	2-3 times /week	Once in 2 weeks	Never/Rarely
Fresh fruit					
Dried fruit e.g. raisins, dried apricots					
Salad and cooked vegetables					
Milk					
Cheese, yogurt					
Bread, cereals, potatoes, rice, pasta					
Meat alternatives e.g. beans, peas, tofu, soy					
Meat (unprocessed) e.g. steak, ham, chicken slices					
Meat (processed) e.g. Burgers, sausages, fried chicken					
Fish/shellfish					
Chocolate					
Chips, Crisps					
Cakes, biscuits, ice cream					
Take away meals e.g. Chinese food, Curry					
Soft drinks					
Caffeine e.g. tea, coffee, power drinks					
Supplements e.g. iron, folate					

Please turn over for the next set of questions

DIRECTIONS: Please **UNDERLINE** the answer which comes closest to how you have felt in the **past week**, not just how you feel today. Here is an example already completed:

I have felt happy:

Yes, all the time

Y<u>es, most of the time</u>

No, not very often

No, not at all

This would mean: I have felt happy most of the time in the past few days.

Please complete the other questions in the same way. Do not take too long over it and try to answer all the questions.

<u>IN THE PAST WEEK</u>

1. I have been able to laugh and see the funny side of things

As much as I always could

Not quite so much now

Definitely not so much now

Not at all

2. I have looked forward with enjoyment to things

As much as I ever did

Rather less than I used to

Definitely less than I used to

Hardly at all

3. I have blamed myself unnecessarily when things went wrong

Yes, most of the time

Yes, some of the time

Not very often

No, never

4. I have been anxious or worried for no good reason

No, not at all

Hardly ever

Yes, sometimes

Yes, very often

5. I have felt scared or panicky for no very good reason

Yes, quite a lot

Yes, sometimes

No, not much

No, not at all

6. Things have been getting on top of me

Yes, most of the time I haven't been able to cope at all

Yes, sometimes I haven't been coping as well as usual

No, most of the time I have coped quite well

No, I have been coping as well as ever

7. I have been so unhappy that I have had difficulty sleeping

Yes, most of the time

Yes, sometimes

Not very often

No, not at all

8. I have felt sad or miserable

Yes, most of the time

Yes, quite often

Not very often

No, not at all

9. I have been so unhappy that I have been crying

Yes, most of the time

Yes, quite often

Only occasionally

No, never

10. The thought of harming myself had occurred to me

Yes, quite often

Sometimes

Hardly ever

Never

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then tick the appropriate box on the right to indicate how you **generally** feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer that seems to describe how you **generally** feel in your recent experience.

	In general….	Almost never	Sometimes	Often	Almost always
1.	I feel pleasant				
2.	I feel nervous and restless				
3.	I feel satisfied with myself				
4.	I wish I could be as happy as others seem to be				
5.	I feel like a failure				
6.	I feel rested				
7.	I am "calm, cool and collected"				
8.	I feel that difficulties are piling up so that I cannot overcome them				
9.	I worry too much over something that really doesn't matter				
10.	I am happy				
11.	I have disturbing thoughts				
12.	I lack self-confidence				
13.	I feel secure				
14.	I make decisions easily				
15.	I feel inadequate				
16.	I am content				
17.	Some unimportant thought runs through my mind and bothers me				
18.	I take disappointments so keenly that I can't put them out of my mind				
19.	I am a steady person				
20.	I get in a state of tension or turmoil as I think over my recent concerns and interests				

Questionnaire Part 2: About your 'GiW' child

- **How old is your child?** ……………………..years ……………………..months
- **How many previous children had you had before you GiW child?** ……………………..
- **What height is your child?** ……………………..cm *OR* ……………………..inches
- **What is your child's weight?** ……………………..kg *OR* …………………….. lbs

- **Did you breastfeed your GiW child?**

  Yes ☐ No ☐ Do not wish to say ☐

  If yes, for how long………………………………….

  If not, what was the main reason?

  Personal preference ☐ I was not able to for medical reasons ☐

  Difficulties breastfeeding ☐ Other………………………………….

- **Does your child have any illness or disability (either physical or mental)?**

  Yes ☐ No ☐ Do not wish to say ☐

  If yes, please specify

  ……………………………………………………………………………………………………

- **Is your child currently on any medication?**

  Yes ☐ No ☐ Do not wish to say ☐

  If yes, please specify what medication

  ……………………………………………………………………………………………………

- **Does your child have any allergies?**

  Yes ☐ No ☐ Do not wish to say ☐

  If yes, please specify

  ……………………………………………………………………………………………………

- **At what age did your child:**

  Say their first word………………..months

  Take their first step………………months

- **Is your child up to date with their vaccinations?**

  Yes ☐ No ☐ Do not wish to say ☐

  If no, which vaccinations have they not had and why

  ………………………………………………………………………………………………………

On the next pages you will see a set of statements that describe children's reactions to a number of situations. We would like you to tell us what your child's reaction is likely to be in those situations. There are of course no "correct" ways of reacting; children differ widely in their reactions, and it is these differences we are trying to learn about. Please read each statement and decide whether it is a "true" or "untrue" description of your child's reaction within the past six months. Use the following scale to indicate how well a statement describes your child:

Circle #	If the statement is:
1	Extremely untrue of your child
2	Quite untrue of your child
3	Slightly untrue of your child
4	Neither true nor false of your child
5	Slightly true of your child
6	Quite true of your child
7	Extremely true of your child

If you cannot answer one of the items because you have never seen the child in that situation, for example, if the statement is about the child's reaction to your singing and you have never sung to your child, then circle NA (not applicable). **Please be sure to circle a number or NA for every item**.

1. Seems always in a big hurry to get from one place to another.

1 2 3 4 5 6 7 NA

2. Gets angry when told s/he has to go to bed.

1 2 3 4 5 6 7 NA

3. Is not very bothered by pain.

1 2 3 4 5 6 7 NA

4. Likes going down high slides or other adventurous activities.

1 2 3 4 5 6 7 NA

5. Notices the smoothness or roughness of objects s/he touches.

1 2 3 4 5 6 7 NA

1	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
Extremely untrue	Quite untrue	Slightly untrue	Neither true nor untrue	Slightly true	Quite true	Extremely true	Not applicable

---

6. Gets so worked up before an exciting event that s/he has trouble sitting still.

1 2 3 4 5 6 7 NA

7. Usually rushes into an activity without thinking about it.

1 2 3 4 5 6 7 NA

8. Cries sadly when a favourite toy gets lost or broken.

1 2 3 4 5 6 7 NA

9. Becomes quite uncomfortable when cold and/or wet.

1 2 3 4 5 6 7 NA

10. Likes to play so wild and recklessly that s/he might get hurt.

1 2 3 4 5 6 7 NA

11. Seems to be at ease with almost any person.

1 2 3 4 5 6 7 NA

12. Tends to run rather than walk from room to room.

1 2 3 4 5 6 7 NA

13. Notices it when parents are wearing new clothing.

1 2 3 4 5 6 7 NA

14. Has temper tantrums when s/he doesn't get what s/he wants.

1 2 3 4 5 6 7 NA

15. Gets very enthusiastic about the things s/he does.

1 2 3 4 5 6 7 NA

16. When practicing an activity, has a hard time keeping her/his mind on it.

1 2 3 4 5 6 7 NA

17. Is afraid of burglars or the "boogie man".

1 2 3 4 5 6 7 NA

18. When outside, often sits quietly.

1 2 3 4 5 6 7 NA

19. Enjoys funny stories but usually doesn't laugh at them.

1 2 3 4 5 6 7 NA

20. Tends to become sad if the family's plans don't work out.

1 2 3 4 5 6 7 NA

21. Will move from one task to another without completing any of them.

1 2 3 4 5 6 7 NA

22. Moves about actively (runs, climbs, jumps) when playing in the house.

1 2 3 4 5 6 7 NA

23. Is afraid of loud noises.

1 2 3 4 5 6 7 NA

24. Seems to listen to even quiet sounds.

1 2 3 4 5 6 7 NA

25. Has a hard time settling down after an exciting activity.

1 2 3 4 5 6 7 NA

26. Enjoys taking warm baths.

1 2 3 4 5 6 7 NA

1	2	3	4	5	6	7	NA
Extremely untrue	Quite untrue	Slightly untrue	Neither true nor untrue	Slightly true	Quite true	Extremely true	Not applicable

---

27. Seems to feel depressed when unable to accomplish some task.

1 2 3 4 5 6 7 NA

28. Often rushes into new situations.

1 2 3 4 5 6 7 NA

29. Is quite upset by a little cut or bruise.

1 2 3 4 5 6 7 NA

30. Gets quite frustrated when prevented from doing something s/he wants to do.

1 2 3 4 5 6 7 NA

31. Becomes upset when loved relatives or friends are getting ready to leave following a visit.

1 2 3 4 5 6 7 NA

32. Comments when a parent has changed his/her appearance.

1 2 3 4 5 6 7 NA

33. Enjoys activities such as being chased, spun around by the arms, etc.

1 2 3 4 5 6 7 NA

34. When angry about something, s/he tends to stay upset for ten minutes or longer.

1 2 3 4 5 6 7 NA

35. Is not afraid of the dark.

1 2 3 4 5 6 7 NA

36. Takes a long time in approaching new situations.

1 2 3 4 5 6 7 NA

37. Is sometimes shy even around people s/he has known a long time.

1 2 3 4 5 6 7 NA

38. Can wait before entering into new activities if s/he is asked to.

1 2 3 4 5 6 7 NA

39. Enjoys "snuggling up" next to a parent or babysitter.

1 2 3 4 5 6 7 NA

40. Gets angry when s/he can't find something s/he wants to play with.

1 2 3 4 5 6 7 NA

41. Is afraid of fire.

1 2 3 4 5 6 7 NA

42. Sometimes seems nervous when talking to adults s/he has just met.

1 2 3 4 5 6 7 NA

43. Is slow and unhurried in deciding what to do next.

1 2 3 4 5 6 7 NA

44. Changes from being upset to feeling much better within a few minutes.

1 2 3 4 5 6 7 NA

45. Prepares for trips and outings by planning things s/he will need.

1 2 3 4 5 6 7 NA

46. Becomes very excited while planning for trips.

1 2 3 4 5 6 7 NA

47. Is quickly aware of some new item in the living room.

1 2 3 4 5 6 7 NA

1	2	3	4	5	6	7	NA
Extremely untrue	Quite untrue	Slightly untrue	Neither true nor untrue	Slightly true	Quite true	Extremely true	Not applicable

---

48. Hardly ever laughs out loud during play with other children.

1 2 3 4 5 6 7 NA

49. Is not very upset at minor cuts or bruises.

1 2 3 4 5 6 7 NA

50. Prefers quiet activities to active games.

1 2 3 4 5 6 7 NA

51. Tends to say the first thing that comes to mind, without stopping to think about it.

1 2 3 4 5 6 7 NA

52. Acts shy around new people.

1 2 3 4 5 6 7 NA

53. Has trouble sitting still when s/he is told to (at movies, church, etc.).

1 2 3 4 5 6 7 NA

54. Rarely cries when s/he hears a sad story.

1 2 3 4 5 6 7 NA

55. Sometimes smiles or giggles playing by her/himself.

1 2 3 4 5 6 7 NA

56. Rarely becomes upset when watching a sad event in a TV show.

1 2 3 4 5 6 7 NA

57. Enjoys just being talked to.

1 2 3 4 5 6 7 NA

58. Becomes very excited before an outing (e.g., picnic, party).

1 2 3 4 5 6 7 NA

59. If upset, cheers up quickly when s/he thinks about something else.

1 2 3 4 5 6 7 NA

60. Is comfortable asking other children to play.

1 2 3 4 5 6 7 NA

61. Rarely gets upset when told s/he has to go to bed.

1 2 3 4 5 6 7 NA

62. When drawing or colouring in a book, shows strong concentration.

1 2 3 4 5 6 7 NA

63. Is afraid of the dark.

1 2 3 4 5 6 7 NA

64. Is likely to cry when even a little bit hurt.

1 2 3 4 5 6 7 NA

65. Enjoys looking at picture books.

1 2 3 4 5 6 7 NA

66. Is easy to soothe when s/he is upset.

1 2 3 4 5 6 7 NA

67. Is good at following instructions.

1 2 3 4 5 6 7 NA

68. Is rarely frightened by "monsters" seen on TV or at movies.

1 2 3 4 5 6 7 NA

69. Likes to go high and fast when pushed on a swing.

1 2 3 4 5 6 7 NA

1	2	3	4	5	6	7	NA
Extremely untrue	Quite untrue	Slightly untrue	Neither true nor untrue	Slightly true	Quite true	Extremely true	Not applicable

---

70. Sometimes turns away shyly from new acquaintances.

1 2 3 4 5 6 7 NA

71. When building or putting something together, becomes very involved in what s/he is doing, and works for long periods.

1 2 3 4 5 6 7 NA

72. Likes being sung to.

1 2 3 4 5 6 7 NA

73. Approaches places s/he has been told are dangerous slowly and cautiously.

1 2 3 4 5 6 7 NA

74. Rarely becomes discouraged when s/he has trouble making something work.

1 2 3 4 5 6 7 NA

75. Is very difficult to soothe when s/he has become upset.

1 2 3 4 5 6 7 NA

76. Likes the sound of words, such as nursery rhymes.

1 2 3 4 5 6 7 NA

77. Smiles a lot at people s/he likes.

1 2 3 4 5 6 7 NA

78. Dislikes rough and rowdy games.

1 2 3 4 5 6 7 NA

79. Often laughs out loud in play with other children.

1 2 3 4 5 6 7 NA

80. Rarely laughs aloud while watching TV or movie comedies.

1 2 3 4 5 6 7 NA

81. Can easily stop an activity when s/he is told "no".

1 2 3 4 5 6 7 NA

82. Is among the last children to try out a new activity.

1 2 3 4 5 6 7 NA

83. Doesn't usually notice odours such as perfume, smoke, cooking, etc.

1 2 3 4 5 6 7 NA

84. Is easily distracted when listening to a story.

1 2 3 4 5 6 7 NA

85. Is full of energy, even in the evening.

1 2 3 4 5 6 7 NA

86. Enjoys sitting on parent's lap.

1 2 3 4 5 6 7 NA

87. Gets angry when called in from play before s/he is ready to quit.

1 2 3 4 5 6 7 NA

88. Enjoys riding a tricycle or bicycle fast and recklessly.

1 2 3 4 5 6 7 NA

89. Sometimes becomes absorbed in a picture book and looks at it for a long time.

1 2 3 4 5 6 7 NA

90. Remains pretty calm about upcoming desserts like ice cream.

1 2 3 4 5 6 7 NA

91. Hardly ever complains when ill with a cold.

1 2 3 4 5 6 7 NA

1	2	3	4	5	6	7	NA
Extremely untrue	Quite untrue	Slightly untrue	Neither true nor untrue	Slightly true	Quite true	Extremely true	Not applicable

---

92. Looks forward to family outings, but does not get too excited about them.

1 2 3 4 5 6 7 NA

93. Likes to sit quietly and watch people do things.

1 2 3 4 5 6 7 NA

94. Enjoys gentle rhythmic activities, such as rocking or swaying.

1 2 3 4 5 6 7 NA

Please turn over for the next set of questions

Below is a list of items that describe children. For each item that describes the child now or within the past 2 months, please circle the 2 if the item is very true or often true of the child. Circle the 1 if the item is somewhat or sometimes true of the child. If the item is not true of the child, circle the 0. Please answer all items as well as you can, even if some do not seem to apply to the child.

Please fill out the questions below to reflect your view of the child's behaviour even if other people might not agree

0 = Not True (as far as you know) 1 = Somewhat or Sometimes True 2 = Very True or Often True.

0 1 2 **1.** Aches or pains (without a medical cause; do not include stomach or headaches)

0 1 2 **2.** Acts too young for age

0 1 2 **3.** Afraid to try new things

0 1 2 **4.** Avoids looking others in the eye

0 1 2 **5.** Can't concentrate, can't pay attention for long

0 1 2 **6.** Can't sit still, restless, or hyper-active

0 1 2 **7.** Can't stand having things out of place

0 1 2 **8.** Can't stand waiting; wants everything now

0 1 2 **9.** Chews on things that aren't edible

0 1 2 **10.** Clings to adults or too dependent

0 1 2 **11.** Constantly seeks help

0 1 2 **12.** Constipated, doesn't move bowels (when not sick)

0 1 2 **13.** Cries a lot

0 1 2 **14.** Cruel to animals

0 1 2 **15.** Defiant

0 1 2 **16.** Demands must be met immediately

0 1 2 **17.** Destroys his/her own things

0 1 2 **18.** Destroys things belonging to his/her family or other children

0 1 2 **19.** Diarrhoea or loose bowels (when not sick)

0 1 2 **20.** Disobedient

0 1 2 **21.** Disturbed by any change in routine

0 1 2 **22.** Doesn't want to sleep alone

0 1 2 **23.** Doesn't answer when people talk to him/her

0 1 2 **24.** Doesn't eat well (describe):
……………………………………………………………………………
……………………………………………………………………………

0 1 2 **25.** Doesn't get along with other children

0 1 2 **26.** Doesn't know how to have fun; acts like a little adult

0 1 2 **27.** Doesn't seem to feel guilty after misbehaving

0 1 2 **28.** Doesn't want to go out of the home

0 1 2 **29.** Easily frustrated

0 1 2 **30.** Easily jealous

0 1 2 **31.** Eats or drinks things that are not food—don't include sweets (describe):
……………………………………………………………………………
……………………………………………………………………………

0 1 2 **32.** Fears certain animals, situations, or places (describe):
……………………………………………………………………………
……………………………………………………………………………

0 1 2 **33.** Feelings are easily hurt

0 1 2 **34.** Gets hurt a lot, accident-prone

0 1 2 **35.** Gets in many fights

0 1 2 **36.** Gets into everything

0 1 2 **37.** Gets too upset when separated from parents

0 1 2 **38.** Has trouble getting to sleep

0 1 2 **39.** Headaches (without medical cause)

0 1 2 **40.** Hits others

0 1 2 **41.** Holds his/her breath

0 1 2 **42.** Hurts animals or people without meaning to

0 1 2 **43.** Looks unhappy without good reason

0 1 2 **44.** Angry moods

0 1 2 **45.** Nausea, feels sick (without medical cause)

0 1 2 **46.** Nervous movements or twitching (describe): ………………………………………………
………………………………………………………………………

0 1 2 **47.** Nervous, highly strung, or tense

0 1 2 **48.** Nightmares

0 1 2 **49.** Overeating

0 1 2 **50.** Overtired

0 1 2 **51.** Panics for no good reason

0 1 2 **52.** Painful bowel movements (without medical cause)

0 1 2 **53.** Physically attacks people

0 1 2 **54.** Picks nose, skin, or other parts of body (describe):
………………………………………………………………………

0 1 2 **55.** Plays with own sex parts too much

0 1 2 **56.** Poorly co-ordinated or clumsy

0 1 2 **57.** Problems with eyes (without medical cause) (describe):
………………………………………………………………………
………………………………………………………………………

0 1 2 **58.** Punishment doesn't change his/her behaviour

0 1 2 **59.** Quickly shifts from one activity to another

0 1 2 **60.** Rashes or other skin problems (without medical cause)

0 1 2 **61.** Refuses to eat

0 1 2 **62.** Refuses to play active games

0 1 2 **63.** Repeatedly rocks head or body

0 1 2 **64.** Resists going to bed at night

0 1 2 **65.** Resists toilet training (describe):
………………………………………………………………………
………………………………………………………………………

0 1 2 **66.** Screams a lot

0 1 2 **67.** Seems unresponsive to affection being given from others

0 1 2 **68.** Self-conscious or easily embarrassed

0 1 2 **69.** Selfish or won't share

0 1 2 **70.** Shows little affection towards people

0 1 2 **71.** Shows little interest in things around him/her

0 1 2 **72.** Shows too little fear of getting hurt

0 1 2 **73.** Too shy or timid

0 1 2 **74.** Sleeps less than most kids during day and/or night (describe):
………………………………………………………………………
………………………………………………………………………

0 1 2 **75.** Smears or plays with bowel movements

0 1 2 **76.** Speech problem (describe):
………………………………………………………………………
………………………………………………………………………

0 1 2 **77.** Stares into space or seems preoccupied

0 1 2 **78.** Stomach aches or cramps (without medical cause)

0 1 2 **79.** Rapid shifts between sadness and excitement

0 1 2 **80.** Strange behaviour (describe):
……………………………………………………………………………
……………………………………………………………………………

0 1 2 **81.** Stubborn, sullen, or irritable

0 1 2 **82.** Sudden changes in mood or feelings

0 1 2 **83.** Sulks a lot

0 1 2 **84.** Talks or cries out in sleep

0 1 2 **85.** Temper tantrums or hot temper

0 1 2 **86.** Too concerned with neatness or cleanliness

0 1 2 **87.** Too fearful or anxious

0 1 2 **88.** Uncooperative

0 1 2 **89.** Underactive, slow moving, or lacks energy

0 1 2 **90.** Unhappy, sad, or depressed

0 1 2 **91.** Unusually loud

0 1 2 **92.** Upset by new people or situations (describe):
……………………………………………………………………………
……………………………………………………………………………

0 1 2 **93.** Vomiting, throwing up (without medical cause)

0 1 2 **94.** Wakes up often at night

0 1 2 **95.** Wanders away

0 1 2 **96.** Wants a lot of attention

0 1 2 **97.** Whining

0 1 2 **98.** Withdrawn, doesn't get involved with others

0 1 2 **99.** Worries

0 1 2 **100.** Please write in any problems the child has that were not listed above.

0 1 2 ……………………………………………………………
……………………………………………………………………………

0 1 2 ……………………………………………………………
……………………………………………………………………………

0 1 2 ……………………………………………………………
……………………………………………………………………………

What concerns you most about the child?

……

Please describe the best things about the child:

……

Please turn over for the next set of questions

Please reflect on the degree to which each of the following statements currently applies to your relationship with your child. Using the scale below, circle the appropriate number for each item.

1 Definitely does not apply   **2** Not really   **3** Neutral, not sure   **4** Applies somewhat   **5** Definitely applies

1. I share an affectionate, warm relationship with my child. 1 2 3 4 5

2. My child and I always seem to be struggling with each other. 1 2 3 4 5

3. If upset, my child will seek comfort from me. 1 2 3 4 5

4. My child is uncomfortable with physical affection or touch from me. 1 2 3 4 5

5. My child values his/her relationship with me. 1 2 3 4 5

6. My child appears hurt or embarrassed when I correct him/her. 1 2 3 4 5

7. My child does not want to accept help when he/she needs it. 1 2 3 4 5

8. When I praise my child, he/she beams with pride. 1 2 3 4 5

9. My child reacts strongly to separation from me. 1 2 3 4 5

10. My child spontaneously shares information about himself/herself. 1 2 3 4 5

11. My child is overly dependent on me. 1 2 3 4 5

12. My child easily becomes angry at me. 1 2 3 4 5

13. My child tries to please me. 1 2 3 4 5

14. My child feels that I treat him/her unfairly. 1 2 3 4 5

15. My child asks for my help when he/she really does not need help. 1 2 3 4 5

16. It is easy to be in tune with what my child is feeling. 1 2 3 4 5

17. My child sees me as a source of punishment and criticism. 1 2 3 4 5

18. My child expresses hurt or jealousy when I spend time with other children. 1 2 3 4 5

19. My child remains angry or is resistant after being disciplined. 1 2 3 4 5

20. When my child is misbehaving, he/she responds to my look or tone of voice. 1 2 3 4 5

21. Dealing with my child drains my energy. 1 2 3 4 5

22. I've noticed my child copying my behaviour or ways of doing things. 1 2 3 4 5

23. When my child is in a bad mood, I know we're in for a long and difficult day. 1 2 3 4 5

24. My child's feelings toward me can be unpredictable or can change suddenly. 1 2 3 4 5

25. Despite my best efforts, I'm uncomfortable with how my child and I get along. 1 2 3 4 5

26. I often think about my child when at work. 1 2 3 4 5

27. My child whines or cries when he/she wants something from me. 1 2 3 4 5

28. My child is sneaky or manipulative with me. 1 2 3 4 5

29. My child openly shares his/her feelings and experiences with me. 1 2 3 4 5

30. My interactions with my child make me feel effective and confident as a parent. 1 2 3 4 5

Thank you very much for answering this questionnaire, your answers are vital in helping us to continue our research into pregnancy and beyond.

Please make sure you have filled out all of the questions and return the completed pack using the self-addressed envelope to:

Samantha Garay,
Sir Martin Evans Building,
Museum Avenue,
Cardiff,
CF10 3AX

If you have any questions email: garaysm@cardiff.ac.uk.

Appendix 2 – Confounding variables in adjusted models

Table No.	Confounding variables	*p*	B or Exp (B)	95% CI
3.14	Maternal age	.106	-.61	-1.35, .13
	Smoking in pregnancy			
	Yes	.002	-17.62	-28.94, -6.29
	No	*ref*	*ref*	*ref*
	Alcohol in pregnancy			
	Yes	.628	-1.68	-8.49, 5.13
	No	*ref*	*ref*	*ref*
	Exercise in pregnancy			
	Yes	.021	-10.39	-19.20, -1.59
	No	*ref*	*ref*	*ref*
	GDM			
	Yes	.012	18.36	4.13, 32.58
	No	*ref*	*ref*	*ref*
	Mode of conception			
	Assisted	.393	-6.65	-21.94, 8.65
	Natural	*ref*	*ref*	*ref*
	WIMD	.016	.01	.00, .01
3.15	Maternal age	.187	1.08	.97, 1.20
	Smoking in pregnancy			
	Yes	.118	2.85	.77, 10.60
	No	*ref*	*ref*	*ref*
	Alcohol in pregnancy			
	Yes	.948	1.04	.34, 3.15
	No	*ref*	*ref*	*ref*
	Exercise in pregnancy			
	Yes	.582	1.62	.29, 8.92
	No	*ref*	*ref*	*ref*
	GDM			
	Yes	.999	.00	.00, .00
	No	*ref*	*ref*	*ref*
	Mode of conception			
	Assisted	.008	9.59	1.80, 51.04
	Natural	*ref*	*ref*	*ref*
	WIMD	.040	.99	1.00, 1.00
4.2	A1 EPDS score	.744	.04	-.19, .27
	BMI at booking	.553	-.06	-.27, .15
	Income			
	< £25,000	.221	-1.94	-5.06, 1.17
	≥ £25,000	*ref*	*ref*	*ref*
4.3	A1 EPDS score	.183	1.06	.98, 1.14
	BMI at booking	< .001	1.21	1.10, 1.32
	Income			
	< £25,000	.232	.55	.20, 1.48
	≥ £25,000	*ref*	*ref*	*ref*
4.4	WIMD	.758	.00	.00, .00
	Education			
	< University	.593	.37	-1.00, 1.75
	≥ University	*ref*	*ref*	*ref*
	Income			
	< £25,000	.098	1.44	-.27, 3.14
	≥ £25,000	*ref*	*ref*	*ref*
	Parity			
	Nulliparous	.803	.17	-1.18, 1.53

Table No.	Confounding variables	*p*	B or Exp (B)	95% CI
	Multiparous	*ref*	*ref*	*ref*
	Fetal sex			
	Male	.807	.14	-.97, 1.24
	Female	*ref*	*ref*	*ref*
	Mental health history			
	Yes	<.001	3.30	2.04, 4.55
	No	*ref*	*ref*	*ref*
4.5	WIMD	.139	1.00	1.00, 1.00
	Education			
	< University	.241	1.88	.66, 5.37
	≥ University	*ref*	*ref*	*ref*
	Income			
	< £25,000	.032	3.51	1.12, 11.03
	≥ £25,000	*ref*	*ref*	*ref*
	Parity			
	Nulliparous	.922	1.05	.37, 2.99
	Multiparous	*ref*	*ref*	*ref*
	Fetal sex			
	Male	.384	.69	.30, 1.59
	Female	*ref*	*ref*	*ref*
	Mental health history			
	Yes	< .001	7.45	3.02, 18.36
	No	*ref*	*ref*	*ref*
4.6	WIMD	.659	.00	.00, .00
	Education			
	< University	.871	.21	-2.37, 2.80
	≥ University	*ref*	*ref*	*ref*
	Income			
	< £25,000	.026	3.63	.43, 6.84
	≥ £25,000	*ref*	*ref*	*ref*
	Parity			
	Nulliparous	.547	-.77	-3.30, 1.75
	Multiparous	*ref*	*ref*	*ref*
	Fetal sex			
	Male	.596	.56	-1.51, 2.62
	Female	*ref*	*ref*	*ref*
	Mental health history			
	Yes	< .001	5.66	3.31, 8.01
	No	*ref*	*ref*	*ref*
4.8	BMI at booking	.531	-.02	.90, 1.05
	Maternal age	.050	1.10	1.00, 1.21
	Education			
	< University	.083	.44	.17, 1.11
	≥ University	*ref*	*ref*	*ref*
	WIMD	.690	1.00	1.00, 1.00
	ELCS delivery			
	No	.210	.56	.03, 5.26
	Yes	*ref*	*ref*	*ref*
4.9	BMI at booking	.297	.95	.86, 1.05
	Maternal age	.054	1.12	1.00, 1.26
	Education			
	< University	.627	.74	.21, 2.54
	≥ University	*ref*	*ref*	*ref*
	WIMD	.604	1.00	1.00, 1.00
	ELCS delivery			

Table No.	Confounding variables		*p*	B or Exp (B)	95% CI
		No	.498	.45	.05, 4.48
		Yes	*ref*	*ref*	*ref*
4.10	A1 EPDS score		.009	.36	.09, .62
	Maternal age		.880	.02	-.27, .31
	Education				
		< University	.349	-1.46	-4.52, 1.61
		≥ University	*ref*	*ref*	*ref*
	Parity				
		Nulliparous	.739	.49	-2.43, 3.41
		Multiparous	*ref*	*ref*	*ref*
4.11	A1 EPDS score		.002	.25	.09, .40
	Maternal age		.486	.06	-.11, .23
	Education				
		< University	.680	-.38	-2.19, 1.44
		≥ University	*ref*	*ref*	*ref*
	Parity				
		Nulliparous	.997	.00	-1.73, 1.73
		Multiparous	*ref*	*ref*	*ref*
4.12	A1 EPDS score		<.001	.51	.23, .80
	Maternal age		.798	.04	-.25, .32
	Education				
		< University	.647	.75	-2.49, 3.99
		≥ University	*ref*	*ref*	*ref*
	Parity				
		Nulliparous	.852	.30	-2.91, 3.51
		Multiparous	*ref*	*ref*	*ref*
5.1	Maternal age		.722	.00	-.02, .01
	GDM				
		Yes	.021	.324	.05, .60
		No	*ref*	*ref*	*ref*
	Mode of conception				
		Assisted	.713	-.05	-.32, .22
		Natural	*ref*	*ref*	*ref*
	WIMD		.085	.00	.00, .00
	Gestational age		<.001	.22	.13, .30
5.3	Maternal age		.194	-.51	-1.27, .26
	GDM				
		Yes	.054	15.39	-.28, 31.05
		No	*ref*	*ref*	*ref*
	Mode of conception				
		Assisted	.486	-5.55	-21.23, 10.43
		Natural	*ref*	*ref*	*ref*
	WIMD		.050	.01	.00, .01
5.4	Maternal age		.187	1.08	.97, 1.20
	GDM				
		Yes	.999	.00	.00, .00
		No	*ref*	*Ref*	*ref*
	Mode of conception				
		Assisted	.008	9.59	1.80, 51.03
		Natural	*ref*	*ref*	*ref*
	WIMD		.040	1.00	1.00, 1.00
5.5	Maternal age		.938	1.00	.92, 1.10

Table No.	Confounding variables		*p*	B or Exp (B)	95% CI
	GDM				
		Yes	.828	1.20	.24, 6.06
		No	*ref*	*ref*	*ref*
	Mode of conception				
		Assisted	.156	2.74	.68, 11.03
		Natural	*ref*	*ref*	*ref*
	WIMD		.258	1.00	1.00, 1.00
5.11	Parity				
		Nulliparous	.927	-.05	-1.11, 1.02
		Multiparous	*ref*	*ref*	*ref*
	WIMD		.906	.00	.00, .00
5.11	Parity				
		Nulliparous	.366	.59	-.71, 1.90
		Multiparous	*ref*	*ref*	*ref*
	WIMD		.587	.00	.00, .00
5.12	Parity				
		Nulliparous	.194	-.70	-1.77, .36
		Multiparous	*ref*	*ref*	*ref*
	WIMD		.082	.00	.00, .00
5.13	Parity				
		Nulliparous	.393	-.16	-.53, .21
		Multiparous	*ref*	*ref*	*ref*
	WIMD		.126	.00	.00, .00
5.15	Parity				
		Nulliparous	.954	-.02	-.69, .65
		Multiparous	*ref*	*ref*	*ref*
	WIMD		.675	.00	.00, .00
5.15	Parity				
		Nulliparous	.871	.02	-.28, .33
		Multiparous	*ref*	*ref*	*ref*
	WIMD		.969	.00	.00, .00
5.15	Parity				
		Nulliparous	.454	-.13	-.47, .21
		Multiparous	*ref*	*ref*	*ref*
	WIMD		.701	.00	.00, .00

BMI, Body Mass Index; WIMD, Welsh Index of Multiple Deprivation; GDM, Gestational Diabetes Mellitus; Ref, reference category; EPDS, Edinburgh Postnatal Depression Scale.

End