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Citation for final published version:

Hawkins, Jemma, Smith, Alexander, Backx, Karianne and Clayton, Debbie 2015. Exercise intensities of gardening tasks within older adult allotment gardeners in Wales. *Journal of Aging and Physical Activity* 23 (2) , pp. 161-168. 10.1123/japa.2013-0171

Publishers page: <http://dx.doi.org/10.1123/japa.2013-0171>

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1  **Exercise Intensities of Gardening Tasks within Older Adult**

2 **Allotment Gardeners in Wales**

1 **Abstract**

2 Previous research has suggested that gardening activity could be an effective form of
3 regular exercise for improving physical and psychological health in later life.

4 However, there is a lack of data regarding the exercise intensities of various
5 gardening tasks across different types of gardening and different populations. The
6 purpose of this study was to examine the exercise intensity of gardening activity for
7 older adult allotment gardeners in Wales, UK following a similar procedure used in
8 previous studies conducted in the USA and South Korea by Park and colleagues
9 (2008a; 2011). Oxygen consumption (VO_2) and energy expenditure for six gardening
10 tasks were measured via indirect calorimetry using the portable Oxycon™ mobile
11 device. From these measures, estimated metabolic equivalent units (METs) were
12 calculated. Consistent with Park et al. (2008a; 2011) the six gardening tasks were
13 classified as low to moderate-high intensity physical activities based on their
14 metabolic values (1.9 - 5.7 METs).

16 **Keywords**

17 Physical activity, energy expenditure, metabolic cost, green exercise, human issues
18 in horticulture

19

20

Introduction

Gardening is a prevalent form of physical activity that is popular with older populations (Chodzko-Zajko et al., 2009). One reason for this may be that gardening has the advantage of not being as stressful to the body as other forms of physical activity such as jogging and aerobic exercise (Restuccio, 1992). In addition, gardening has been shown to be a meaningful and purposeful leisure activity for older adults (Hawkins, Mercer, Thirlaway & Clayton, 2013) which may be particularly important in retirement (Dunnett & Qasim, 2000). The popularity of gardening presents an opportunity to encourage engagement in gardening activity in later life as a means of health promotion and protection.

Various international physical activity guidelines have highlighted gardening as a beneficial form of “everyday” or “recreational” activity which can strengthen muscles whilst having a very low injury risk (Department of Health, 2011; US Department of Health and Human Services, 2008). Other research has outlined potential benefits of gardening for healthy aging such as providing a long-term focus, an adaptable yet challenging workout, a method of reducing risk of falls, and a stress-busting enjoyable activity (Chen & Janke, 2012; Milligan, Gatrell & Bingley, 2004; Park, 2007; Sommerfeld, Waliczek & Zajicek, 2010). Gardening is also expected to influence an individual’s whole body bone mineral density as it involves weight-bearing motions such as pushing a mower, digging holes, pulling weeds and carrying soil and water, whilst incorporating the whole body including most upper limb muscles (Park et al., 2013; Turner, Bass, Ting, & Brown, 2002). Research suggests that whilst performing these activities over 82 percent of gardeners bend, 59 percent walk, and 47 percent lift for durations of ten seconds or longer (Park & Shoemaker, 2009). Findings from Chen & Janke (2012) indicate that gardening is associated with

1 better health status in terms of the number of chronic conditions and functional
2 limitations reported by older adults. Furthermore, gardening has been associated
3 with improvements in various other physical health outcomes such as lower total
4 cholesterol, lower blood pressure, and lower mortality (Armstrong, 2000; Walsh,
5 Pressman, Cauley, & Browner, 2001). For example, one study revealed that
6 individuals who performed only gardening activities for more than 60 minutes per
7 week had 66 percent less chance of primary cardiac arrest than individuals who were
8 physically inactive (Lemaitre et al., 1999).

9 Gardening can also have beneficial effects on cognitive and psychological
10 health. For example, gardening has also been linked to protection against cognitive
11 decline because of the cognitively demanding mental stimulation of many gardening
12 tasks as well as the physical activity involved (Infantino, 2005; Simons, Simons,
13 McCallum & Friedlander, 2006). In addition, gardening has been found to be an
14 empowering experience that can build self-esteem and relieve stress (Wakefield,
15 Yeudall, Taron, Reynolds, & Skinner, 2007). Several studies have consistently shown
16 that regular engagements in gardening can lead to reduced reactivity to stress
17 (Weyerer & Kupfer, 1994), lower likelihood of depression (Teychenne, Ball, &
18 Salmon, 2008), and decreased risk of stress-related diseases such as cardiovascular
19 disease (Jeon, Lokken, Hu, & van Dam, 2007). More specifically, involvement in
20 allotment gardening has been linked to enhanced health and well-being and also to
21 sustainable behavior (Bacon, Brophy, Mguni, Mulgan, & Shandro, 2010; Hawkins,
22 Thirlaway, Backx & Clayton, 2011). In the United Kingdom, allotment gardens are
23 legally defined in the Allotments Acts as “a piece of land not exceeding 40 poles in
24 extent which is wholly or mainly cultivated by the plot-holder for the production of
25 vegetables or fruit by him/herself and family” (Allotments Regeneration Initiative,
26 2007). An allotment site consists of a collection of allotment plots where plot-holders

1 garden individually but in close proximity to one another, thus offering the opportunity
2 for social interaction (Milligan *et al.*, 2004). The new UK physical activity guidelines in
3 particular highlight allotment gardening as an important means of being active that
4 enables older adults to maintain independence and social engagement, which can
5 also improve well-being (Department of Health, 2011).

6 It has been suggested that gardening can also be adapted to various levels of
7 physical ability and fitness level. Furthermore, a few gardening tasks have been
8 reported as forms of moderate intensity physical activity in the literature (Ainsworth *et*
9 *al.*, 2000), there is limited research that has directly determined the exercise intensity
10 of various gardening tasks in older adults. Park, Shoemaker and Haub (2008a)
11 conducted one of the rare studies in this area; calculating the energy expenditure of
12 older adults engaged in various gardening tasks. Energy expenditure was calculated
13 by monitoring the heart rates of the participants during a number of gardening tasks
14 and using oxygen consumption data from a laboratory-based submaximal graded
15 exercise test on a treadmill. The metabolic equivalents (METs) of the gardening tasks
16 were calculated in terms of oxygen consumption per unit of body mass (1 MET = 3.5
17 ml·kg⁻¹·min⁻¹) (Ainsworth *et al.*, 2011). MET values of less than 3 indicate low
18 intensity activities, 3-6 METs are considered to be moderate intensity, while anything
19 over 6 METs is high or vigorous physical activity (Pate *et al.*, 1995). Park *et al.*
20 showed that the gardening tasks could be classified as either low or moderate
21 intensity physical activities. They identified gardening tasks which use both the upper
22 and lower body such as digging and raking as moderate intensity physical activities.
23 Whereas tasks that primarily use the upper body, such as hand weeding and
24 transplanting seedlings, were identified as low intensity physical activity.

25 Park *et al.*'s original study (2008a) used a sample of eight American older
26 adults to investigate gardening activity intensities on garden plots created specifically

1 for the research. Park, Lee, & Son (2011) have also recently replicated these findings
2 in a sample of 20 Korean older adults aged 65 and over and expanded upon the
3 original study by incorporating six more gardening tasks. All fifteen gardening tasks
4 were determined to be low to moderate intensity physical activities (1.7 - 4.5 METs).
5 This suggests that gardening may provide the same health benefits received from
6 non-gardening forms of physical activity by contributing to an overall active lifestyle.

7 Despite the growing evidence surrounding the benefits of gardening for older
8 adults' physical and mental health, there is a lack of research that specifically
9 focuses on determining the benefits of an acute bout of gardening activity. In
10 addition, the compendium of physical activities (Ainsworth et al., 2011) does not
11 determine the precise energy cost of physical activity within individuals, but instead
12 provides an activity classification system that standardizes the MET intensities of
13 physical activity. Thus, it does not account for differences in age when performing an
14 activity. Although Park and colleagues (Park et al., 2008a; 2011) have started to
15 investigate exercise intensities of gardening activities in older adults as previously
16 outlined, these were conducted with samples from the USA and Korea, and as such
17 there is a need to validate their findings in other settings across the world. The
18 physical activity intensities of gardening tasks may vary according to geographical
19 location due to a number of factors, such as climate, altitude, weather and soil type.
20 In order to gain an ecologically valid measure for an international classification of the
21 intensity of gardening tasks it is vital that studies are conducted in different
22 geographical settings.

23 The present study thus comprised a partial replication of Park et al.'s
24 examination of exercise intensities of gardening activity (2008a; 2011). In the interest
25 of creating a more externally valid result, participants were asked to perform the
26 gardening tasks in the same manner they would on their own allotment rather than as

1 instructed by the experimenter. This way the result can be compared to everyday
2 gardening on an allotment. An advancement on Park et al.'s (2008a) original study in
3 the USA was also made in the method of measuring oxygen consumption during the
4 gardening tasks. Park et al. (2008a) interpolated oxygen consumption values from a
5 laboratory treadmill test to calculate energy expenditure of gardening tasks
6 examined. The present study used a more sophisticated approach, in line with Park
7 et al. (2011), by employing the use of a portable device to measure participants'
8 oxygen consumption as they completed the gardening tasks.

9 The present study aimed to expand the evidence base related to the exercise
10 intensity of gardening tasks by recruiting experienced allotment gardeners rather
11 than community-dwelling older adults (with no specific gardening history) as studied
12 in Park et al.'s research. Allotment gardening may be particularly salient to the
13 current older generation in the UK as it was originally a post-war form of welfare
14 provision, and data now shows that it is a common leisure activity within the older
15 population (Milligan et al., 2004). We have previously suggested that because
16 allotment gardens are typically larger than the average home garden, allotment
17 gardening may require more regular attendance and thus contribute larger quantities
18 of physical activity to an individual's weekly levels (Hawkins et al., 2011). If this is the
19 case; it is feasible to suggest that allotment gardeners may reach higher physical
20 activity intensities when carrying out gardening tasks. Perhaps, those experienced in
21 conducting gardening tasks may be more efficient and have higher levels of
22 motivation to complete these.

23 The recommendation of allotment gardening as a leisure pursuit for promoting
24 health and wellbeing in later life requires the extension of the existing data on
25 exercise intensity of gardening tasks to a sample of allotment gardeners.

26 Furthermore, in order to provide an accurate picture of the physical activity intensities

1 of gardening it is vital that data are gathered about the physical activity intensity
2 levels of gardening tasks among a population who have varying levels of experience
3 in gardening and in different settings across the world. Park and colleagues have
4 presented key data regarding novice or non-gardeners in the USA and Korea. The
5 aim of the present study was to determine the exercise intensity levels of a range of
6 gardening tasks in an experienced allotment gardener population in a UK setting.

9 **Method**

10 **Participants**

11 The inclusion criteria for the present study required that participants were Welsh
12 allotment gardeners currently holding a tenancy of at least one plot of land. Fifty-nine
13 Welsh allotment gardeners had participated in a previous research study,
14 investigating the physiological and psychological benefits of gardening, and had
15 given consent to be re-contacted about future research studies. These 59 individuals
16 were considered for inclusion in the present study through an anonymous search of
17 the existing database to establish individuals that met the inclusion criteria.

18 Consistent with Park et al.'s previous studies, the inclusion criteria required that
19 participants: were over the age of 60, were able to attend the University for
20 completion of the study, were non-smokers, and had no uncontrolled chronic
21 disease, no heart and lung disease, no pace maker, ability to kneel, and had
22 answered 'no' to all questions on the Physical Activity Readiness Questionnaire
23 (PAR-Q; Canadian Society for Exercise Physiology, 2002). The PAR-Q is a medical
24 screening tool for establishing safety to take part in physical activity and contains
25 questions such as "Do you feel pain in your chest when you do physical activity?".

26 Thirty potential participants met the inclusion criteria and were invited to take part in

1 the study via an invitation letter containing a full information sheet detailing the study
2 procedures and requesting individuals to telephone or email the researcher if they
3 wished to participate in the study. Twenty-one individuals responded to the letter; of
4 which three declined participation in the study. The remaining 18 individuals
5 expressed their willingness to participate and were subsequently enrolled to take part
6 in the study.

7 Participants were provided with a schedule and information package
8 providing details of experimental and ethical procedures prior to their participation in
9 the study. Additionally, participants were advised to abstain from caffeine and a
10 heavy meal two hours prior to participating in the study, and to wear comfortable
11 clothing including a pair of boots suitable for gardening activity. An incentive of £10
12 was provided to participants upon completion of the study.

14 **Procedure**

15 Each session began with an explanation of the study and its requirements, after
16 which participants had the opportunity to ask any questions before completing an
17 informed consent form. Participants completed six of the nine gardening tasks used
18 by Park et al. (2008a) between July and September 2012 (see Table 1 for
19 descriptions of the tasks). The gardening tasks were selected to include activities at
20 ground level and at a workbench with various motions such as kneeling, squatting,
21 bending or standing. Other gardening tasks included by Park and colleagues (2008a;
22 2011) were not included due to their similarity to those tasks already selected and to
23 reduce the burden on participants' time.

24 The gardening tasks were orally described to participants before the
25 experiment began, and prior to each task being carried out the researcher physically
26 demonstrated the components of the task. Participants were advised to complete

1 each gardening task in the same manner they would if they were at their allotment.
2 The participants' completed each task for 10 minutes followed by a five minute
3 resting time while sitting on a chair. Ten minutes has been established as a sufficient
4 time to reach maximum heart rate in older adults (Park et al., 2008a). The
5 participants were also free to take a rest during any of the gardening tasks due to
6 fatigue; however no participants chose to do so. Participants completed all six
7 gardening tasks in one session in the following order: weeding, raking, digging,
8 mixing soil, filling containers with soil, and sowing seeds. The order of these tasks
9 was based on the work of Park et al. (2008a) and was designed to replicate regular
10 gardening.

11 The materials required for the gardening tasks included a hand fork, rake,
12 shovel, bucket, pots (approximately 65), and packets of seeds. Two gardening plots
13 were created specifically for use in this study on the campus of Cardiff Metropolitan
14 University, Cardiff, Wales, UK, next to a grassy area with weeds for the weeding
15 task. Temperature and humidity were measured using a portable weather station
16 (Orgeon Scientific) prior to the participant engaging in gardening activity, the mean
17 outside temperature was 21.94°C (SD \pm 3.71) and the mean humidity was 49.57%
18 (SD \pm 9.30).

19 Each participant wore the portable Oxycon™ device; this involved wearing
20 a mask over their mouth while carrying a small telemetric transmitter on their back.
21 The participant's heart rate was also continuously monitored throughout the
22 gardening tasks using a chest strap monitor (Polar Electro, RS4000, Kemple,
23 Finland) which recorded heart rate via radiotelemetry to the base station of the
24 portable Oxycon™ device. Participants were advised to complete each gardening
25 task in the same manner they would if they were at their allotment.

1 **Measures**

2 ***Sociodemographic Characteristics.*** In order to provide a detailed description of
3 the sample, several sociodemographic characteristics were collected. These
4 included: age, gender, ethnicity, hours of current gardening per week, educational
5 attainment and employment status. Height and body mass were also measured to
6 allow a calculation of body mass index [body mass (kg) / height² (m²)], height was
7 measured using a fixed stadiometer (Holtain LTD, Pembrokeshire, Wales) and body
8 mass was measured using electronic weighing scales (Vogel & Halke, SECA-Model
9 770, Hamburg, Germany).

10
11 ***Exercise Intensity.*** A portable Oxycon™ mobile device (Jaeger, Oxycon Mobile,
12 Warwickshire, England) was used to measure oxygen consumption (VO₂) and a
13 measurement of heart rate when combined with a polar chest strap. The Oxycon™
14 mobile is a portable, wireless metabolic system measuring gas exchange breath by
15 breath while attached to the body in a vest system. Air flow is detected by the rotation
16 of a low resistance, bidirectional turbine connected to a face mask. Not only has the
17 Oxycon™ mobile device been validated for use with older adults (Spruit et al., 2011)
18 it has also been validated in comparisons with the Douglas bag method (Perret &
19 Mueller, 2006; Rosdahl, Gullstrand, Salier-Eriksson, Johansson, & Schantz, 2010),
20 which is generally considered to be the most accurate way to measure indirect
21 calorimetry, and under field conditions (Salier-Eriksson, Rosdahl, & Shantz, 2011)
22 including strong external winds and extended moderate physical activity (45 min)
23 outdoors at low temperatures and high humidity. Via a sampling line connected to the
24 flow sensor unit the expired air is analyzed for O₂ and CO₂ concentrations, this data
25 is collected by an exchange unit which sends the data telemetrically to a base station
26 connected to a computer. The portable Oxycon™ mobile device was chosen over

1 Park et al.'s (2008a) multi-stepped approach because it is more convenient for use
2 outdoors without losing validity or accuracy (Rosdahl et al., 2010). After 30 minutes
3 of warm up and immediately before data collection a 2-point (0.2 and 2.01 s⁻¹) air
4 flow calibration was performed using the automatic flow calibrator. Gas analyzer was
5 calibrated against room air and a certified gas mixture of 16% O₂, 5% CO₂ and 79%
6 N₂ together with determination of measurement delay time. Before the start of data
7 collection the face mask was checked for leakage and gas exchange values were
8 checked to be within normal limits.

10 **Data Analysis**

11 MET values for each gardening task were determined from measured levels of VO₂,
12 by dividing the measured VO₂ by 3.5 as 1 MET = 3.5 ml·kg⁻¹·min⁻¹. In order to
13 calculate energy expenditure (EE), first the average respiratory exchange ratio
14 (RER), which is provided by the portable Oxycon™ mobile device, was calculated for
15 each gardening task. Using a Zuntz table (McArdle, Katch & Katch, 2001) kcal per
16 liter of O₂ was derived from the RER, this was then multiplied by the participants
17 measured level of absolute VO₂ (litres·min⁻¹) to determine kcal·min⁻¹. EE was then
18 calculated (kj·kg⁻¹·hour⁻¹ = kcal·min⁻¹·4.184·kg⁻¹ of body mass).

19 Each participant's physiological data were recorded continuously using the
20 portable Oxycon™ mobile device. For each gardening task the initial and final minute
21 of data measured during the task was discarded in order to reduce noise between
22 the end and beginning of a task. A one-way ANOVA with post hoc test Duncan's
23 multiple range was conducted at $p < .05$ in order to compare means of physiological
24 data and metabolic rates for the six gardening tasks. Paired t-tests were also
25 performed to compare energy expenditure and metabolic values of gardening tasks

1 classified as low, moderate and high intensity activity. All data were analyzed using
2 the Statistical Package for Social Sciences (SPSS) version 19 for Windows.

3 4 **Results**

5 **Descriptive Data**

6 Demographic characteristics of the study sample are summarized in Table 2. The
7 majority of participants were of Caucasian ethnicity, were evenly split between males
8 and females and were all retired. Age ranged from 62 to 70, with a mean of 65 years
9 (SD ± 1.93). Most participants were normal or overweight according to the World
10 Health Organization's BMI classification systems, with a mean BMI of 25.62 (SD
11 ± 2.91). Participants reported spending anywhere between 2 hours per week to 23
12 hours per week gardening in the current season, with a mean of 11 hours per week
13 (SD ± 6.71).

14 15 **Exercise Intensities of Gardening Tasks**

16 The six gardening tasks completed by participants ranged from low to high intensity
17 physical activities (Table 3). Digging had a mean of 5.7 METs (SD ± 1) and was
18 therefore classed as a high-moderate intensity activity (~ 6 METs). Raking (4.6 ± 0.8),
19 weeding (4.6 ± 0.8), and mixing soil (3.2 ± 0.5) were all classed as moderate physical
20 activities (3-6 METs). Filling containers (2.3 ± 0.6) and sowing seeds (1.9 ± 0.5) were
21 both classed as low intensity activities (1-3 METs). The results of independent t-tests
22 showed that there were no significant differences between male and female
23 participants for any of the metabolic measurements on all six gardening tasks.

24 As seen in Table 4, energy expenditure during high-moderate intensity
25 gardening tasks (M = 24.33, SE = 1.19) was found to be significantly greater than
26 energy expenditure during both moderate intensity gardening tasks (M = 19.80, SE =

1 1.19), $t(13) = -4.84$, $p < .0001$, $r = .80$, and low intensity gardening tasks ($M = 9.85$, SE
2 $= 0.61$), $t(13) = -10.44$, $p < .0001$, $r = 0.94$. Furthermore energy expenditure during
3 moderate intensity gardening tasks ($M = 20.01$, $SE = 0.77$) was significantly greater
4 than energy expenditure during low exercise intensity gardening tasks ($M = 9.1$, $SE =$
5 0.46), $t(24) = -12.26$, $p < .0001$, $r = 0.93$.

6 MET values for high-moderate intensity gardening tasks ($M = 5.7$, $SE = 0.27$)
7 were found to be significantly different to MET values for both moderate intensity
8 gardening tasks ($M = 4.6$, $SE = 0.26$), $t(13) = -5.10$, $p < .0001$, $r = 0.82$, and low
9 intensity gardening tasks ($M = 2.1$, $SE = 0.14$), $t(13) = -10.41$, $p < .0001$, $r = 0.94$. MET
10 values for moderate intensity gardening tasks ($M = 4.6$, $SE = 0.17$), were also found
11 to be significantly different from MET values of low intensity gardening tasks ($M =$
12 2.1 , $SE = 0.11$), $t(24) = -12.47$, $p < .0001$, $r = 0.93$.

14 Discussion

15 The aims of this study were to partially replicate the work of Park and colleagues
16 (2008a; 2011) in a sample of Welsh older adult allotment gardeners in order to
17 determine whether gardening is an effective form of exercise for this population. All
18 six gardening tasks were determined to be low to high-moderate intensity physical
19 activities based on their metabolic values (1.9 - 5.7 METs).

20 As noted at the outset little attention has focused on determining the exercise
21 intensities of various gardening tasks in older adults, despite the well documented
22 benefits of gardening on older adults' physical, psychological, mental and social
23 wellbeing. In two previous studies Park and colleagues (2008; 2011) have concluded
24 that a variety of gardening tasks provide low to moderate intensity physical activity for
25 healthy older adults in America and Korea. By exploring the exercise intensities of
26 gardening tasks in a Welsh allotment gardening population the present study has

1 provided further empirical support for gardening as an effective form of physical
2 activity in older adults that can contribute to the achievement of public health
3 recommendations.

4 Out of the six gardening tasks measured in adults over the age of 60 digging
5 was found to be the most intensive with a MET value of 5.7 (SD \pm 1.0), and as such
6 was classified as a high-moderate intensity physical activity. Raking, weeding, and
7 mixing soil were identified as moderate physical activity (4.6 \pm 0.8 METs, 4.6 \pm 1.0
8 METs , and 3.2 \pm 0.5 METs respectively) while filling containers with soil and sowing
9 seeds were identified as low intensity physical activity (2.3 \pm 0.6 METs, and 1.9 \pm 0.5
10 METs respectively). No significant differences were observed between male and
11 female participants across all gardening tasks on any of the metabolic
12 measurements. It is worth noting that this lack of a gender difference might be
13 specific to the sample of experienced allotment gardeners of this study. It would be
14 interesting to determine whether there are gender differences in the metabolic cost of
15 gardening activities amongst a non-experienced population.

16 The majority of the MET values for gardening tasks in this study were slightly
17 higher than those previously reported by Park and colleagues' (2008a; 2011)
18 American and Korean samples. For example digging was found to be a higher
19 intensity physical activity within our sample with an average of 5.7 METs (SD \pm 1.0),
20 than the 3.6 METs (SD \pm 0.8) reported in Park's American study (Park et al., 2008a)
21 and the 4.5 METs (SD \pm 1.2) reported in Park's Korean study (Park et al., 2011).

22 Park et al. (2011) explain that differences between gardening intensities for
23 similar gardening tasks may be due to how the task is performed; gardening tasks
24 can be performed using different tools (e.g., type, weight), methods, or with different
25 conditions (e.g., compactness of soil, garden size). Thus the differences reported
26 here may be due to the participants being able to complete the tasks in the same

1 manner as they would on their allotment plot, rather than following the demonstration
2 of a researcher as was the case in Park et al.'s studies. It is possible that the
3 participants' previous experience of cultivating an allotment plot may have been
4 implicated in the higher MET values observed in this study when compared with Park
5 et al.'s findings. The exercise intensity required to dig over a large allotment plot may
6 be greater than is typical of the domestic gardening of a community-dwelling older
7 adult population as studied by Park et al. According to Gunn et al. (2004; 2005)
8 exercise intensity of gardening tasks can also be influenced by variables such as
9 environment and participant characteristics (e.g., age, participant's physical fitness).
10 As such the observed differences between MET values may have occurred as a
11 result of the lower average age of this study's sample (65.2 ±1.9 years old) compared
12 to that of Park's American (77.4 ±4.1 years old) and Korean (67.3 ±2.7 years old)
13 samples. It is also unknown whether participants exercised at a different intensity
14 than usual as a consequence of being measured and observed. However attempts
15 were made to reduce this issue by regularly reminding participants that all gardening
16 tasks should be performed at the same intensity as if they were on their allotment
17 and not being measured by the researcher. It is also possible that allotment
18 gardeners exercise at a greater intensity due to their presumed higher motivation to
19 engage in these tasks as compared with the non-gardener samples in Park et al.'s
20 research.

21 In order to determine MET values for physical activity Park et al. (2008)
22 measured oxygen uptake (VO_2) through a submaximal graded exercise test (GXT)
23 on a treadmill based on the heart rate measurements from the gardening tasks. This
24 indirect method of estimating exercise intensity is based on a linear relationship
25 between heart rate and VO_2 during daily activities, work and sports (Park et al.,
26 2011). Unlike Park et al. (2008a) this study has used a portable and lightweight

1 metabolic measurement system, the Oxycon™ Mobile. This method of indirect
2 calorimetry also has the advantage of being simple to use and less time consuming
3 for participants. The Douglas bag method is generally considered to be the most
4 accurate method of indirect calorimetry. Although the Douglas bag method may be
5 used for measurements in an outside environment, its limitations in sampling duration
6 as well as measurement resolution means the Oxycon™ mobile was more suited to
7 the study's aims. Furthermore, the bags restrict freedom of movement and can
8 impose additional air resistance (Rosdahl et al., 2010).

9 In their previous studies Park and colleagues (2008a; 2011) have identified
10 gardening tasks that use a combination of the upper body and lower body, such as
11 digging, turning compost, raking, mulching and fertilizing to be moderate intensity
12 physical activities for older adults (3-6 METs). Whereas tasks that use primarily the
13 upper body such as mixing soil, filling container with soil, sowing seeds and
14 transplanting seeds have been identified as low intensity physical activity (1-3 METs).
15 Correspondingly, results from the current study suggest that gardening tasks which
16 involve weight-bearing motions and combine both upper and lower body muscle
17 strength are classed as moderate to high intensity physical activity. For example,
18 digging over soil with a shovel uses both upper and lower body muscles while
19 incorporating weight-bearing motions (Park & Shoemaker, 2009; Restuccio, 1992).
20 Weight bearing motions such as the ones used during gardening are expected to
21 influence whole body bone mineral density (Turner et al., 2002) as well as
22 incorporating many important elements of accepted exercise regimes such as
23 strength and stance, repetition and movement, and even resistance principals similar
24 to those seen in weight training (Park & Shoemaker, 2009). Therefore an activity
25 program that incorporates gardening tasks of moderate-high intensity physical

1 activity can be expected to improve or maintain the health of older adults (Armstrong,
2 2000; Park & Shoemaker, 2009; Reynolds 1999; 2002; Turner et al., 2002).

3 Furthermore, knowing the intensities of various gardening tasks can help to
4 formulate activity programs suitable for older adults according to their health
5 conditions or level of physical ability. For example, Park, Lee, Son and Shoemaker
6 (2012) have tested a range of horticultural therapy programs for exercise intensity.
7 They found that creating a vegetable garden consists of a range of moderate
8 physical activity gardening tasks, resulting in the overall activity, 'making a garden',
9 being classified as a moderate intensity physical activity. Whereas completing activity
10 programs like propagating herbs or transplanting seedlings were found to be low
11 intensity physical activities and would therefore be suitable for individuals that require
12 a lower level of physical activity or have other special needs.

13 Gardening has the advantage of being a directed and long term focus activity
14 (Restuccio, 1992) as it involves the responsibility of taking care of a garden
15 continuously (Relf, 1981) and this may promote regular and long-term involvement.
16 In addition, gardening can help maintain motivation and interest, which has proven to
17 be difficult with physical activity in older adults (Brawley et al., 2003). As a result,
18 gardening activity may be a particularly beneficial form of exercise to promote for the
19 goal of healthy ageing, enabling older people to live healthier lifestyles for longer.
20 According to Welmer, Mörck, & Dahlin-Ivanoff (2012) older adults do not view
21 physical activity as a separate activity but rather as a part of other leisure activities
22 often rated as more important than the physical activity itself. As an activity that is
23 already popular with older adults in the UK, allotment gardening therefore can be
24 seen as a form of leisure activity that provides exercise intensity levels that can meet
25 government recommendations. In this study, allotment gardeners reported average
26 weekly gardening activity levels of 10.97 hours a week (± 6.71). Thus, even at the

1 lowest levels of participation, allotment gardening provided a level of physical activity
2 to contribute significantly to the achievement of current public health
3 recommendations (i.e. 150 minutes of moderate to vigorous intensity activity per
4 week). Whilst it could be argued that domestic gardening may not require as frequent
5 participation as tending to an allotment garden plot, this activity would still contribute
6 to an overall active lifestyle and achievement of weekly physical activity
7 recommendations when combined with other active leisure pursuits. The importance
8 of incremental daily physical activities for reducing the risk of cardiovascular
9 morbidity and all-cause mortality in later life has recently been highlighted by
10 researchers in Sweden (Ekblom-Bak et al., 2013). In addition, other work by Park,
11 Shoemaker and Haub (2008b) suggests that domestic gardening can require high
12 levels of participation at certain times of the year.

13 It should be noted that healthy, non-smoking participants were deliberately
14 selected to participate in this study in order to replicate Park et al.'s previous studies,
15 and that this presents a possible bias in the findings. Different intensity values may
16 have been observed with a less healthy sample. Additionally, participants were self-
17 selecting and may have been more highly motivated to promote the benefits of
18 gardening. Future replication of this research with clinical populations is warranted to
19 examine any differences in intensity levels of gardening tasks across specific
20 conditions. Unlike in Park et al.'s previous work (Park et al., 2011; 2012), resting
21 metabolic rate was not measured in this study. Therefore it is not possible to
22 compare the metabolic equivalents of the gardening tasks reported here to the
23 participants' metabolic rate when at rest.

24 An additional limitation of this research is the small sample size, which
25 replicates but does not improve upon the sample sizes of previous work (Park et al.,
26 2008a; 2011). Future research that expands on this study should aim to recruit a

1 larger sample. Additional research is also needed in order to determine the
2 effectiveness of physical activity programs incorporating gardening activities for older
3 adults, particularly low intensity activity programs in adults with low levels of physical
4 ability. Longitudinal studies could be particularly useful in determining the health
5 benefits of low or moderate intensity gardening tasks over time.

6 In conclusion, the present study indicates that a range of gardening tasks
7 provide low to high-moderate intensity physical activity (1.9 - 5.7 METs) for healthy
8 older adults. In addition, we have partially-replicated the findings of Park et al.
9 (2008a; 2011) in a sample of Welsh allotment gardeners and found that some
10 activities were conducted at a higher intensity than the non-allotment gardener
11 participants of Park et al.'s studies. The range of MET values observed for the
12 various gardening tasks studied is comparable to the MET values provided for
13 walking activity in the Compendium of Physical Activities (Ainsworth et al., 2011). For
14 example, slow walking at less than a 2 mph pace (2.0 METs) is comparable to
15 sowing seeds (1.9 METs) and walking at a more vigorous pace of 4-4.5 mph (5-6
16 METs) is comparable to digging activity (5.7 METs). This highlights the relevance of
17 gardening as a valuable resource for disease prevention and health promotion in
18 older populations. The introduction of gardening as an integral component in older
19 adults' physical activity programs may have significant physical and psychosocial
20 benefits for the health in later life.

21 22 **Acknowledgements**

23 The authors would like to thank the participants who kindly took time out of their daily
24 lives to volunteer with the research. The authors would also like to thank Mike
25 Stembridge, Physiology Technician at the Cardiff School of Sport, for his assistance

1 with this research. Thanks are also extended to the reviewers of this manuscript for
2 their helpful comments and suggestions.

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1 **Table 1 Descriptions of Gardening tasks to be performed**

Gardening Tasks	Description
Hand Weeding	With a standard hand fork (wood and stainless steel), squatting or sitting in a grassy area with weeds, some moving as they complete an area.
Raking	Raking a 2 m x 2.5 m garden plot with a standard soil rake (wood and stainless steel), including the removal of stones, weeds, and bark from the surface.
Digging	Digging over a 2 m x 2.5 m garden plot with a standard digging shovel (wood and stainless steel). Participants were informed not to dig a big hole.
Mixing Soil	Mixing and moving soil between two buckets (30 cm diameter) with their hands, performed while the bucket was standing on a table (table dimensions: 110 cm x 55 cm x 76 cm).
Filling Containers with Soil	Filling 6 cm fiber pots with previously mixed soil from a bucket (30 cm diameter) by hand, performed while the bucket was standing on a table (table dimensions: 110 cm x 55 cm x 76 cm).
Sowing Seeds	Creating a small hole in previously filled pots with either finger or a small stick and then sowing beetroot seeds (<i>Beta vulgaris</i>) and covering over.

1 **Table 2 Descriptive Characteristics of the Participants**

Variable	<i>M</i> ± <i>SD</i>	%
Age (years)	65.21 ± 1.93	
Gender: Male		50
Ethnicity: Caucasian		92.9
Body Mass (kg)	70.96 ± 12.23	
Height (m)	1.66 ± 0.08	
Body Mass Index (kg·m ⁻²)	25.62 ± 2.91	
Gardening Activity*	10.97 ± 6.71	
Education:		
Undergraduate		71.4
Graduate		21.4
Postgraduate		7.1
Employment Status:		
Retired		100

2 *Note.* *hours per week, *N* =18.

1 **Table 3 Metabolic measurements for six different gardening tasks**

Task	VO₂ (mL·kg⁻¹·min⁻¹)	EE (kJ·kg⁻¹·h⁻¹)	METs	HR (beats·min⁻¹)
Digging	19.8 ^a ± 3.5	24.3 ^a ± 4.4	5.7 ^a ± 1.0	111 ^a ± 14
Raking	16.2 ^b ± 2.9	20.1 ^b ± 3.7	4.6 ^b ± 0.8	102 ^a ± 17
Weeding	16.1 ^b ± 3.4	19.8 ^b ± 4.4	4.6 ^b ± 1.0	100 ^a ± 17
Mixing Soil	11.1 ^c ± 1.9	13.6 ^c ± 2.5	3.2 ^c ± 0.5	91 ^b ± 16
Filling Containers	8.1 ^d ± 1.9	9.8 ^d ± 2.4	2.3 ^d ± 0.6	83 ^b ± 10
Sowing Seeds	6.8 ^d ± 1.6	8.3 ^d ± 2.0	1.9 ^d ± 0.5	77 ^b ± 8

2 *Note.* Values are $M \pm SD$, a, b, c, and d: means sharing one common letter are not significantly
3 different by Duncan's multiple range test at $p=.05$. VO₂ = oxygen consumption; EE = energy
4 expenditure; METs = metabolic equivalents; HR = heart rate.

1 **Table 4 Classifying six gardening tasks as low, moderate, or high**
 2 **intensity physical activity**
 3

	Exercise Intensity			t	df
	Gardening Tasks Low Intensity	Gardening Tasks Moderate Intensity	Gardening Tasks High Intensity		
EE (Kj·kg ⁻¹ ·h ⁻¹)	9.10 ± 2.30	20.01 ± 3.83		-12.26*	24
	9.85 ± 2.27		24.33 ± 4.44	-10.44*	13
		19.80 ± 4.46	24.33 ± 4.44	-4.84*	13
METs	2.1 ± 0.5	4.6 ± 0.8		-12.47*	24
	2.3 ± 0.5		5.7 ± 1.0	-10.41*	13
		4.6 ± 1.0	5.7 ± 1.0	-5.10*	13

4 *Note.* Values are $M \pm SD$, * = $p < .0001$.