Gardening Tasks Performed by Adults are Moderate- to High-Intensity Physical Activities

Sin-Ae Park[1], A-Young Lee[1], Kwan-Suk Lee[2], and Ki-Cheol Son[1,3]

Additional index words. **Cosmed K4b^2, energy expenditure, horticultural therapy, metabolic equivalents, socio-horticulture**

Summary. **The objective of this study was to determine the exercise intensities of 10 gardening tasks for men and women in their 20s. Fifteen university students [(mean ± SD) age 24.7 ± 1.4 years and body mass index 23.5 ± 4.1 kg·m^{-2}] participated in this study. On two occasions, the subjects completed 10 gardening tasks in a high tunnel and a grassy area with weeds located near the high tunnel in Cheongju, Chungbuk, South Korea. They performed five gardening tasks randomly ordered on each occasion. Subjects did each gardening task for 5 minutes and then sat and rested in a chair for 5 minutes before the next task. Each subject wore a portable telemetric calorimeter and respired into the facemask during the gardening tasks and resting periods to measure their oxygen uptake. The subjects also wore a heart rate monitor under their breast to record heart rate data during the gardening tasks and resting periods via radiotelemetry. The 10 gardening tasks performed by the subjects were determined to be moderate- to high-intensity physical activities [3.5 ± 0.5 to 6.3 ± 1.2 metabolic equivalents (MET)]. In conclusion, the exercise intensity of gardening tasks should be useful information for developing garden exercise programs that meet the recommended physical activity for health benefits in adults.**

The MET is a measure of the exercise intensity of physical activity (Ainsworth et al., 2000). One MET is equal to 3.5 mL·kg^{-1}·min^{-1} oxygen and represents the exercise intensity of lying down and meditating (Ainsworth et al., 2011). Values < 3 MET indicate low-intensity physical activities, 3 to 6 MET indicate moderate-intensity physical activities, and >6 MET indicate high-intensity physical activities (Pate et al., 1995). To benefit adult health, at least 30 min of moderate-intensity (3 to 6 MET) physical activity on most days of the week is recommended (Nelson et al., 2007; Pate et al., 1995). Participation in physical activity that meets this recommendation may lead to health benefits such as a reduced risk of chronic diseases, increased fitness level, and improved independent living ability (American College of Sports Medicine, 1993, 1998, 2004; DiPietro, 2001; U.S. Department of Health and Human Services, 1996).

Gardening is a popular leisure-time activity that provides physical and mental health benefits such as lower total cholesterol, lower blood pressure, lower mortality, better hand function ability, higher bone mineral density, better psychological well-being, and better social integration (Armstrong, 2000; Park et al., 2009; Reynolds, 1999, 2002; Turner et al., 2002; Walsh et al., 2001). Park et al. (2008, 2011, 2012) reported that various gardening tasks were low- to moderate-intensity physical activities for adults over 65 years old. For this age group, gardening tasks that used both the upper and lower body at the same time, such as digging, raking, planting, etc., were of moderate intensity and could provide the same health benefits as non-gardening forms of physical activities (Park et al., 2009); whereas tasks such as harvesting, mixing soil, etc. that mainly used the upper body were low intensity. Moreover, vegetable garden programs that mainly combined moderate-intensity gardening tasks such as digging, raking, planting, etc. were overall moderate-intensity physical activities for older adults, and indoor horticultural activity programs such as propagating herbs and transplanting were overall low-intensity physical activities combining mainly low-intensity gardening tasks.

The exercise intensity of physical activity may differ between age groups and fitness levels (Norton et al., 2010). There are not enough data on the MET of gardening tasks in different age groups to develop a garden exercise program for maintaining or improving health conditions. Therefore, the objective of this study was to determine the exercise intensity of various common gardening tasks in adults in their 20s.

Materials and methods

Subjects. University students in their 20s were recruited from the Chungbuk National University in Cheongju, Chungbuk, South Korea. The volunteers were recruited by word of mouth. In addition to age, the criteria for participation were that the students had no current diseases and did not smoke. Fifteen adults who met the inclusion criteria volunteered to participate in the study. In this study, the sample size was selected to determine the metabolic costs of gardening tasks on the basis of professional advice from exercise physiologists and our previous research experience in measuring the MET of various gardening tasks by using a portable telemetric calorimeter system for pulmonary gas exchange measurement with breath-by-breath analysis (Park et al., 2011, 2012, 2013a). In an orientation, the description of the experimental procedures and schedule were provided and a printed informed consent form was obtained. Subjects were required to not consume caffeine or alcohol, eat a heavy meal, or do physical activity for 12 h before each test session. The subjects visited the garden plot on

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
9.2303	calorie(s)/lb	kJ·kg^{-1}	0.1083
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
36.1273	inch^3/lb	mL·kg^{-1}	0.0277
0.4536	lb	kg	2.2046
4.8824	lb/ft^2	kg·m^{-2}	0.2048
28.3495	oz	g	0.0353
(°F – 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

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[1]Department of Environmental Health Science, Konkuk University, Seoul 143-701, South Korea

[2]Department of Industrial Engineering, Hongik University, Seoul 121-791, South Korea

[3]Corresponding author. E-mail: kcson@konkuk.ac.kr.

two occasions, and a gift card (U.S. $10) as an incentive was received for each visit at the completion of the test session.

Experimental procedures. Ten common gardening tasks were performed by the subjects in a high tunnel and in a nearby grassy area with weeds for weeding and a vegetable garden for harvesting in Cheongju, Chungbuk, South Korea. The subjects visited the garden plot twice to complete the 10 gardening tasks (Table 1), and they performed five gardening tasks randomly ordered on each occasion (Fig. 1).

Subjects did each gardening task for 5 min and then had a 5-min resting time where they sat in a chair. In previous studies (Park et al., 2008, 2011, 2012), this length of time for performing garden tasks and resting was found to be sufficient for metabolic measurements of gardening tasks. During the 5-min resting time, researchers demonstrated the next gardening task and the subjects were required to not move or speak. All test sessions were completed during Aug. 2012. The average temperature and humidity were (mean ± SD) 29.6 ± 5.4 °C and 76.5 ± 17.2% during the test, respectively (Acuba CS-201 digital hygro-thermometer; Chosun, Guangdong, China).

Measurement. Each subject wore a portable telemetric calorimeter (K4b^2; Cosmed, Rome, Italy) and respired into the facemask during the gardening tasks and resting periods to measure their oxygen uptake. The calorimeter comprised a portable telemetric transmitter, facemask, flow meter, gas analyzer, receiver, and temperature probe (HR-TEMP) and it measures metabolic parameters such as oxygen uptake, energy expenditure, and MET. The calorimeter was calibrated for oxygen and carbon dioxide analysis before starting each test session (Park et al., 2011, 2012). The Douglas bag method is generally considered as the most accurate indirect calorimetry, but it is not practical in outside laboratory settings (Doyon et al., 2001; Kawakami et al., 1992; McLaughlin et al., 2001). The K4b^2 calorimeter is a portable system that is proper to measure outdoor activities such as gardening and it has the same validity and accuracy as the Douglas bag method. The subjects also wore a heart rate monitor under their breast to record heart rate data during the gardening tasks and resting periods via radiotelemetry (Polar T 31; FitMed, Kempele, Finland).

The height without shoes of each subject was measured using an anthropometer (Ok7979; Samhwa, Seoul, South Korea), and the weight and body composition without shoes [fat (grams), lean mass (grams), and percent fat] were measured using a body fat analyzer (ioi 353; Jawon Medical, Gyeongsan, South Korea). The body mass index was calculated from the weight and height data {i.e., body mass index = [weight (kilograms)]/[height (meters)]^2}. The resting metabolic rate and heart rate were measured using a portable calorimetric instrument (K4b^2) with a radiotelemetry monitor (Polar T 31) while the subject rested in a chair for 5 min before starting the first test session. The age-adjusted maximum heart rate was calculated as 208 – 0.7 × age (Tanaka et al., 2001).

Table 1. Descriptions of gardening tasks performed by adults that participated in the study to determine the exercise intensities of gardening tasks.

Gardening tasks	Descriptions[z]
Digging	Digging a 1.5 × 2-m garden plot with a shovel (1.3 kg)
Raking	Raking a 1.5 × 2-m garden plot with a rake (0.9 kg)
Weeding	Bending or squatting in a grassy area and weeding using a hand fork (0.3 kg); some movement required when they finished an area
Mulching	Applying straw mulch in a previously prepared bed with lettuce plants in a 1.5 × 2-m garden plot
Hoeing	Hoeing a 1.5 × 2-m garden plot with a hand hoe (0.3 kg)
Sowing	Digging a row with a hand trowel (0.1 kg), sowing bean seeds (*Phaseolus vulgaris*) and covering them with soil
Harvesting	Harvesting lettuce (*Lactuca sativa*) and korean sesame leaf (*Perilla frutescens* var. *crispa*) planted in a 5 × 9-m garden plot
Watering	Watering a 4 × 18-m garden plot using a hose
Mixing growing medium	Mixing growing medium (7 peatmoss:3 perlite) in a bucket (50 cm diameter, 15 cm tall) by hand with water added from a watering can (1.8 kg), performed while the bucket was standing on a 0.4 × 0.3 × 0.6-m table
Planting transplants	Transplanting lettuce into a 1.5 × 2-m garden plot using a hand trowel (0.1 kg)

[z]1 m = 3.2808 ft, 1 cm = 0.3937 inch, 1 kg = 2.2046 lb.

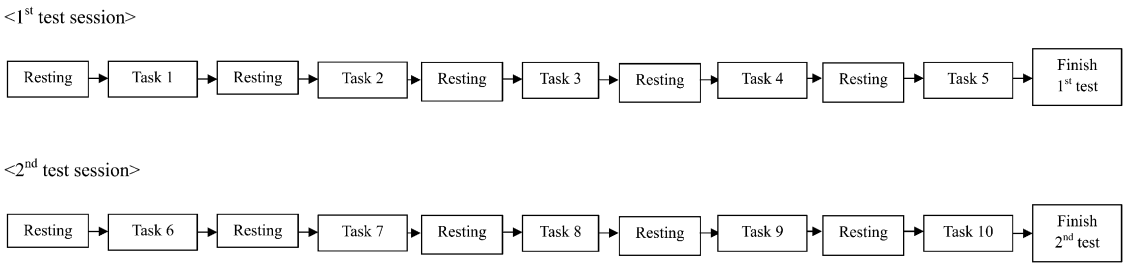

Fig. 1. Experimental procedure of gardening tasks performed by adults who participated in the study to determine the exercise intensities of gardening tasks. Subjects visited garden plot twice to complete the 10 gardening tasks. They performed five gardening tasks for each visit and the gardening tasks were randomly selected for each subject. Subjects did each gardening task for 5 min and then had a 5-min resting time between each task by sitting on a chair.

DATA ANALYSIS. Descriptive information was handled using Excel (Microsoft Office 2007; Microsoft Corp., Redmond, WA). Scheffé test at $P < 0.05$ was used to compare means of metabolic rates for the 10 gardening tasks for all subjects, calculated using SPSS (version 18 for Windows; IBM, Armonk, NY). For each gardening task, data for the first 10 s were deleted to compensate for the time required to walk to the garden plot to start the task.

Results

CHARACTERISTICS OF THE SUBJECTS. The average age of the 15 Korean subjects (six males, nine females) was (mean ± SD) 24.7 ± 1.4 years. The average body mass index was normal 23.5 ± 4.1 kg·m^{-2} (Table 2).

EXERCISE INTENSITIES OF GARDENING TASKS PERFORMED. The 10 gardening tasks were determined to be moderate- to high-intensity physical activities for the subjects [3.5 ± 0.5 to 6.3 ± 1.2 MET (Table 3)]. Most of the gardening tasks were of moderate-intensity for adults: planting transplants (3.5 ± 0.5 MET), mixing growing medium (3.6 ± 0.5 MET), watering (3.9 ± 0.4 MET), harvesting (4.2 ± 0.6 MET), sowing (4.3 ± 0.8 MET), hoeing (4.4 ± 0.8 MET), mulching (4.5 ± 0.6 MET), weeding (5.0 ± 0.8 MET), and raking (5.4 ± 1.0 MET). Tasks such as watering, mixing growing medium, and planting transplants were of lower intensity than the other gardening tasks among the moderate-intensity gardening tasks ($P < 0.05$). Digging was a high-intensity physical activity (6.3 ± 1.2 MET) and the most intense task tested in this study ($P < 0.05$).

In addition, the mean MET values of the 10 gardening tasks were higher in males than in females but the differences were small (data not shown). In particular, the average MET values of digging, raking, and hoeing for males were about 1 MET higher than those for females.

Discussion

Most of the gardening tasks performed by the Korean adults in their 20s in this study were moderate-intensity physical activities (Table 3). In the compendium of physical activity by Ainsworth et al. (2011), about 30 gardening tasks, such as planting trees, raking lawns, and trimming shrubs or trees, were also moderate-intensity physical activities for adults aged 18 to 65 years based on published or estimated data by experts.

The exercise intensity of typical physical activities, such as walking, may differ on the basis of age (Harrell et al., 2005). The mean MET value of the activities was higher in the younger age group than in the older age group. For example, the MET values for walking were 7.02 MET in children 8 to 11 years of age and 5.78 MET in children 13 to 15 years of age (Harrell et al., 2005). Previous studies have also shown that the exercise intensities of gardening tasks differ on the basis of the age group (Park et al., 2013a). Younger age groups showed higher MET values for most of the gardening tasks than the older age groups. Park et al. (2013a) reported that the range for MET values of gardening tasks conducted by children 11 to 13 years of age [(mean ± SD) 4.3 ± 0.5 to 6.6 ± 1.6 MET] was a little higher than that for MET values of the same gardening tasks conducted by the adults in their 20s in this study (Table 3). The exercise intensities of common gardening tasks performed by older adults over 65 years of age were lower than those of common gardening tasks performed by children 11 to 13 years of age [4.3 ± 0.5 to 6.6 ± 1.6 MET (Park et al., 2013a)] and adults in their 20s (Table 3).

There was little difference in MET values of gardening tasks between genders (data not shown). Tasks such as digging, raking, and hoeing among the 10 gardening tasks showed higher MET values for males than females (about 1 MET difference). Brooks et al. (2004) and Gunn et al. (2005) reported that MET values for lawn mowing for Australian males and females were 5.6 ± 1.0 and 6.0 ± 1.0 MET, respectively, in a laboratory setting.

The exercise intensity of physical activity may differ due to gender, age, body mass, adiposity, individual functional capacity, efficiency of movement, and geographic environmental conditions where the activities are performed (Abadi et al., 2010; Ainsworth et al., 2000; Norton et al., 2010). When gardening, differences in the type or weight of garden tools, gardening methods, garden conditions such as the type and compactness of the soil, and garden size can all affect the intensity of gardening tasks (Park et al., 2011). In previous studies, the MET values of some gardening tasks such as raking, mulching, and hand weeding were lower for older American gardeners (mean age 77.4 ± 4.1 years) than for older Korean gardeners (mean

Table 2. Descriptive information of adults who participated in the study to determine the exercise intensities of gardening tasks.

Variable	Mean	SD
Age (years)	24.7	1.4
Height (cm)[z]	170.4	7.0
Body wt (kg)[y]	68.6	13.4
Body composition[y]		
Body mass index (kg·m^{-2})	23.5	4.1
Fat (g)	16,286.7	7,405.9
Lean (g)	48,326.7	9,715.3
Percent fat (%)	23.4	7.7
Resting metabolic rate[x]		
VO_2 (mL·kg^{-1}·min^{-1})[w]	5.7	0.9
Energy expenditure (kJ·kg^{-1}·h^{-1})[v]	6.8	1.1
Resting MET[u]	1.6	0.3
Resting heart rate (beats/min)[t]	82.5	18.4
Age-adjusted HRmax (beats/min)[s]	195.3	1.4

[z]Height without shoes was measured by an anthropometer (Ok7979; Samhwa, Seoul, South Korea); 1 cm = 0.3937 inch.
[y]Measured by a body fat analyzer (ioi 353; Jawon Medical, Gyeongsan, South Korea); 1 kg = 2.2046 lb, 1 kg·m^{-2} = 0.2048 lb/ft^2, 1 g = 0.0353 oz.
[x]Measured by a portable calorimetric instrument (K4b^2; Cosmed, Rome, Italy) while the subject sat on a chair for a 5-min resting before starting the first test session.
[w]Oxygen uptake; 1 mL·kg^{-1} = 0.0277 inch^3/lb.
[v]1 kJ·kg^{-1} = 0.1083 calorie/lb.
[u]1 metabolic equivalents (MET) = 3.5 mL·kg^{-1} (0.0969 inch^3/lb) oxygen per minute (Norton et al., 2010).
[t]Heart rate by a radiotelemetry monitor (Polar T 31; FitMed, Kempele, Finland) while the subject sat on a chair for a 5-min resting before starting the first test session.
[s]Age-adjusted maximum HR (HRmax) = 208 – 0.7 × age (Tanaka et al., 2001).

age 67.3 ± 2.7 years) although the gardening tasks were all low to moderate intensity (Park et al., 2008, 2011).

For generalization of the MET results in this study of adults in their 20s, the sample size was decided on the basis of professional advice from exercise physiologists and our previous research experience in measuring the MET of various gardening tasks by using a portable system to measure outdoor gardening tasks with high accuracy and validity (Park et al., 2011, 2012, 2013a). Previous studies generally used about 20 subjects to measure the exercise intensity and energy expenditure of physical activities (Fischer et al., 2004; Gunn et al., 2002). Moreover, a convenience sample that met specific criteria, such as specific age range, and provided descriptive information for the participants in this study could support the generalizability of the sample.

Knowing the exercise intensity of a physical activity is valuable information when exercise is prescribed. There are specific challenges and risks associated with prescribing exercise, such as determining when the exercise intensity exceeds an individual's physical capacity, or when a high relative intensity is prescribed in the absence of prior conditioning. These situations often need to be considered when working with people who have limited physical capacities or chronic illness or are engaged in rehabilitation programs (Norton et al., 2010). In this aspect, when gardening tasks are applied in an exercise program as an exercise prescription or horticultural therapy program for clients with special needs, the MET data will be useful for developing a proper program considering the physical capacity of participants.

Extensive research has found that regular physical activity that meets the physical activity recommendation of at least 30 min of moderate intensity on most days of the week may lead to health benefits such as a reduction in chronic disease and improvements in fitness levels, aerobic capacity, balance, etc. (American College of Sports Medicine, 1993, 1998, 2004; DiPietro, 2001; U.S. Department of Health and Human Services, 1996). However, only a few populations meet this recommended level and many have less physically active lifestyles for

Table 3. Metabolic measurements of adults in their 20s (mean age 24.7 ± 1.4 years) during 10 gardening tasks to determine the exercise intensities.

Gardening tasks	Mean	SD
Digging		
MET[z]	6.3 a[y]	1.2
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)[x]	22.0 a	4.0
Heart rate (beats/min)	131.2 a	11.2
Energy expenditure ($kJ \cdot kg^{-1} \cdot h^{-1}$)[w]	26.1 a	4.5
HRmax (%)[v]	43.6 a	10.8
Raking		
MET	5.4 ab	1.0
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	18.7 a	3.5
Heart rate (beats/min)	126.2 ab	13.5
Energy expenditure ($kJ \cdot kg^{-1} \cdot h^{-1}$)	22.6 ab	3.9
HRmax (%)	40.2 ab	11.7
Hoeing		
MET	4.4 bcd	0.8
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	15.5 bcd	2.9
Heart rate (beats/min)	116.3 abc	11.8
Energy expenditure ($kJ \cdot kg^{-1} \cdot h^{-1}$)	18.8 bcd	3.3
HRmax (%)	30.6 abc	11.4
Weeding		
MET	5.0 bc	0.8
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	17.2 bc	2.7
Heart rate (beats/min)	118.0 abc	13.6
Energy expenditure ($kJ \cdot kg^{-1} \cdot h^{-1}$)	20.6 bc	2.9
HRmax (%)	33.2 abc	13.3
Mulching		
MET	4.5 bcd	0.6
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	15. 7 bcd	2.0
Heart rate (beats/min)	112.1 abc	12.4
Energy expenditure ($kJ \cdot kg^{-1} \cdot h^{-1}$)	18.6 bcd	2.0
HRmax (%)	26.0 bc	9.4
Sowing		
MET	4.3 bcd	0.8
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	14.9 bcd	2.9
Heart rate (beats/min)	109.3 bc	12.6
Energy expenditure ($kJ \cdot kg^{-1} \cdot h^{-1}$)	18.0 bcd	3.6
HRmax (%)	24.3 bc	11.1
Harvesting		
MET	4.2 cd	0.6
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	14.6 cd	2.1
Heart rate (beats/min)	109.6 bc	12.3
Energy expenditure ($kJ \cdot kg^{-1} \cdot h^{-1}$)	17.7 cd	2.8
HRmax (%)	26.0 bc	10.4
Watering		
MET	3.9 cd	0.4
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	13.5 cd	1.5
Heart rate (beats/min)	113.0 abc	12.5
Energy expenditure ($kJ \cdot kg^{-1} \cdot h^{-1}$)	16.4 cd	2.3
HRmax (%)	27.6 abc	11.7
Mixing growing medium		
MET	3.6 d	0.5
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	12.7 c	1.8
Heart rate (beats/min)	109.6 bc	12.2
Energy expenditure ($kJ \cdot kg^{-1} \cdot h^{-1}$)	15.5 d	2.6
HRmax (%)	24.9 bc	9.6
Planting transplants		
MET	3.5 d	0.5
VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	12.1 c	1.6

(*Continued on next page*)

Table 3. (*Continued*) Metabolic measurements of adults in their 20s (mean age 24.7 ± 1.4 years) during 10 gardening tasks to determine the exercise intensities.

Gardening tasks	Mean	SD
Heart rate (beats/min)	105.8 c	11.0
Energy expenditure ($kJ \cdot kg^{-1} \cdot h^{-1}$)	14.6 d	2.0
HRmax (%)	20.9 c	9.7

[z]1 metabolic equivalents (MET) = 3.5 $mL \cdot kg^{-1}$ (0.0969 $inch^3$/lb) oxygen per minute (Norton et al., 2010).
[y]Means sharing a common letter are not significantly different by Scheffé test at $P < 0.05$.
[x]Oxygen uptake; 1 $mL \cdot kg^{-1}$ = 0.0277 $inch^3$/lb.
[w]1 $kJ \cdot kg^{-1}$ = 0.1083 calorie/lb.
[v]Maximum heart rate (HRmax) = 208 – 0.7 × age (Tanaka et al., 2001).

reasons such as the inconvenience, dullness, or monotony of activities and the cost of exercise equipment and fees (Patricia and Deborah, 2002; Restuccio, 1992). Anecdotal evidence suggests that exercise intervention in outdoor natural environments or urban green spaces may be better for maintaining long-term exercise than indoor exercise interventions (Bird, 2004). Motivating people to spend time participating in outdoor activities such as gardening, conservation work, gentle to vigorous sporting activities in natural environments, etc. is crucial to make people more active (Department of Health, 2009).

Gardening is a popular leisure time (Armstrong, 2000) and outdoor activity that may lead to a more physically active lifestyle (Park et al., 2008, 2009; van den Berg et al., 2010). Park et al. (2008) reported that older American gardeners spent an average of 33 h gardening in May and 15 h in June and July in a Kansas observational study and allotment gardening promoted an active lifestyle in the Netherlands (van den Berg et al., 2010) because gardeners had to regularly care for their garden. Gardening is a dynamic activity because of changes in seasons and plant growth cycles, and this helps provide motivation for regular participation by providing interest and changes throughout the seasons (Park et al., 2008).

Moreover, American gardeners over 65 years of age that spent more than 150 min/week in their gardens showed better self-reported physical health conditions and hand function ability (grip strength and pinch force) than those who did less gardening or no gardening (Park et al., 2009; Park and Shoemaker, 2009) because gardening was a physical activity that met physical activity recommendations for health and because many common gardening tasks include a gripping motion (Park et al., 2008, 2011, 2012; Park and Shoemaker, 2009). Gardening tasks may also improve muscle strength and fitness levels because they are weight-bearing motions that use various muscles (Park et al., 2013b; Turner et al., 2002).

In addition, gardening as a physical activity provides additional benefits such as social networking, a feeling of connectivity and companionship, an increased appreciation of nature, improvements in self-esteem, and a means of escape from modern life (Barton et al., 2009; Peacock et al., 2007; Pretty et al., 2007).

In conclusion, the exercise intensity of gardening tasks should be a useful information for developing garden exercise programs based on physical activity recommendations for health benefits. Moreover, it would be a valuable data when developing a horticultural therapy program based on the physical capacity of a client. Future studies are required to investigate the exercise intensity of various gardening programs that are a series of garden tasks for developing a gardening exercise intervention or horticultural therapy program for health benefits. It would be interesting to apply a long-term garden exercise program to investigate the health benefits of male and female adults.

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