

The Metabolic Costs of Gardening Tasks in Children

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SUMMARY. The metabolic cost of 10 gardening tasks was measured in children to determine the exercise intensities associated with these tasks. Seventeen children [(mean $\pm$ SD) aged 12.4 ± 0.7 years and body mass index 21.6 ± 4.0 kg·m⁻²] participated in this study. The children performed the 10 gardening tasks at a garden previously established in Cheongju, Chungbuk, South Korea. They visited the garden twice and performed five different tasks on each visit. Five minutes were provided to complete each gardening task and a 5-minute rest was allowed between each task. The children wore a portable telemetric calorimeter and a heart rate monitor for measurement of oxygen uptake and heart rate during the gardening tasks. The results show that the 10 gardening tasks represented moderate- to high-intensity physical activity for the children [4.3 ± 0.5 to 6.6 ± 1.6 metabolic equivalents (MET)]. Digging (6.6 ± 1.6 MET) and raking (6.2 ± 1.5 MET) were high-intensity physical activities, and digging was more intense than the other gardening tasks performed in this study ($P < 0.05$). Tasks such as weeding (5.8 ± 1.1 MET), mulching (5.5 ± 1.3 MET), hoeing (5.3 ± 0.7 MET), sowing seeds (5.0 ± 1.1 MET), harvesting (4.8 ± 0.6 MET), watering (4.6 ± 1.1 MET), mixing growing medium (4.4 ± 0.6 MET), and planting transplants (4.3 ± 0.5 MET) were moderate-intensity physical activities. The MET data for the gardening tasks will facilitate the development of garden-based exercise interventions for children, which can promote health and physically active lifestyle.

Physical activity is “bodily movement that is produced by the contraction of skeletal muscle and that substantially increases energy expenditure” [U.S. Department of Health and Human Services (HHS), 1996]; this definition includes incidental physical activity, such as housework and walking for transportation (Caspersen et al., 1985). Metabolic equivalents are used to express the exercise intensity associated with a physical activity (Norton et al., 2010). The MET value for a specific physical activity can be determined on the basis of the oxygen consumption per unit of body mass while performing the activity [1 MET = 3.5 mL·kg⁻¹·min⁻¹ oxygen (Norton et al., 2010)]. The intensity of physical activities can be classified as low (less than 3 MET), moderate (3 to 6 MET), and high

(higher than 6 MET) (Pate et al., 1995). For example, the resting metabolic rate, which is recorded while one is lying down, is 1 MET, sitting quietly is 1.3 MET, walking for pleasure involves 3.5 MET as a moderate-intensity activity, and jogging involves 7.5 MET as a high-intensity activity (Ainsworth et al., 2011).

Despite the health benefits of physical activity, many children have low physical activity levels and a sedentary lifestyle (Taveras et al., 2007). Physical inactivity in childhood may lead to a sedentary lifestyle in adulthood (Malina, 2001; Telama et al., 1997), increasing the risk for diseases in the future (HHS, 1996). The barriers to physical activity in children are:

a preference for indoor activities such as viewing television or playing video/computer games, time constraints, unsafe neighborhoods, a lack of motivation, hesitation caused by perceived incompetence or lack of skill, a lack of resources, and insufficient social support from parents and peers (Burdette and Whitaker, 2005; Norman et al., 2005; O’Dea, 2003; Rees et al., 2006; Spear et al., 2007; Taveras et al., 2007). Thus, to encourage participation in regular physical activity, effective strategies are needed. In particular, factors such as enjoyment and fun are important components to keep children motivated and interested in participating in an intervention (Baranowski et al., 2008; Borra et al., 1995; Epstein et al., 2007; Mellecker and McManus, 2008). Children may show an improvement in health conditions such as type 2 diabetes and obesity by meeting the physical activity recommendations for health benefits; i.e., at least 60 min of daily moderate- to vigorous-intensity physical activity (Biddle et al., 1998; Bundred et al., 2001; Department of Health, 2004; London and Guranitz, 2013; McCue et al., 2013; Siwik et al., 2013; Stamatakis et al., 2005; Strong et al., 2005).

Gardening provides a hands-on experience in the process of growing plants and helps children understand the life cycle of plants and the ecosystem (Montessori, 1964; Morris et al., 2000). Gardening is a dynamic activity because of seasonal variations and plant growth cycles (Park et al., 2008a); therefore, it may maintain children’s interest and curiosity. Moreover, school gardening has been reported to elicit positive effects, such as improved science achievement (Dirks and Orvis, 2005; Klemmer et al., 2005a, 2005b; Mabie and Baker, 1996; Smith and Motsenbocker, 2005) and eating habits, including increased fruit and vegetable intake (Lineberger and Zajicek,

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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
1.6093	mph	km·h ⁻¹	0.6214
28.3495	oz	g	0.0353
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

2000; McAleese and Rankin, 2007; Morris et al., 2001, Morris and Zidenberg-Cherr, 2002) in children.

In previous studies, gardening was determined to be a physical activity that can involve energy expenditure (Park et al., 2008a, 2008b, 2011, 2012a, 2012b). Various common gardening tasks, such as digging, raking, planting, mulching, harvesting, and watering, were low- to moderate-intensity physical activities in older adults over 65 years of age. Most of the gardening tasks that were tested in older adults were moderate-intensity physical activities in adults in their twenties (Park et al., 2012a). In Ainsworth et al. (2011), ≈ 30 of the lawn and gardening tasks were classified as moderate-intensity physical activities in adults below 65 years of age, on the basis of published or estimated data. However, there is not enough data on the metabolic costs of gardening tasks, especially in children. Therefore, the metabolic costs of these tasks were measured to determine the corresponding exercise intensities and effectiveness of these tasks as a physical activity in children. The results can be used to develop a gardening program for children to achieve proper levels of physical activity for health benefits.

Materials and methods

PARTICIPANTS. Children between 11 and 13 years of age were recruited from the community in Cheongju, Chungbuk, South Korea. The children aged 11 to 13 years were targeted in this study because of the availability of the measurement tool (i.e., small, medium, and large sizes of the facemask for the metabolic cost measurement are provided. The small size is available for the higher-grade elementary school children). A flyer with a description of the purpose, requirement, time schedule, etc., of this study and a registration form were distributed at churches, community centers, and directly to individuals by acquaintances. The flyer was also posted on bulletin boards in residential areas. Criteria required that participants in this study be between 11 and 13 years of age and free of known diseases. A written informed consent form from the children's parents or caregivers was also required for participation in this study. Seventeen Korean children (13 boys, 4 girls)

volunteered for this study and the sample size of 17 was statistically large enough to generalize to the population of interest. The average age and body mass index was (mean $\pm$ SD) 12.4 ± 0.7 years and 21.6 ± 4.0 kg·m⁻², respectively. The children were requested to not eat a heavy meal and to not perform physical activity before at least 12 h of testing. They were also instructed to wear proper clothes, shoes, and gloves for gardening. As an incentive, each child received a gift card (US\$10) at the completion of all test sessions.

EXPERIMENTAL PROCEDURES. Ten gardening tasks, namely, digging, raking, weeding, mulching, hoeing, sowing seeds, harvesting, watering, mixing growing medium, and planting transplants, were conducted by the children in a high tunnel which is a shade area and a grassy area located next to the high tunnel; both sites were located in Cheongju, Chungbuk, South Korea (Table 1). The researchers sectionalized the grassy area for weeding and previously cultivated the vegetables such as lettuce (*Lactuca sativa*) and Korean sesame leaf (*Perilla frutescens* var. *crispa*) for harvesting near the high tunnel. The children visited the garden plot twice and conducted five different garden tasks during each visit. The researchers drew lots to randomly decide the order of gardening tasks for each child.

Five minutes were provided for each gardening task, and a 5-min rest was given between each task, during which the child was required to sit on a chair. The amount of time for the gardening task and rest was previously determined to be enough for metabolic measurement of gardening tasks in a preliminary study (Park et al., 2011). In the study, 5 min for activity or resting was sufficient to measure the metabolic costs and recover heart rate to its resting rate. Throughout the entire test session, the children wore the measurement tools for measuring metabolic cost and were asked to not speak. During the resting period, the researchers demonstrated or verbally explained the next gardening task. All measures of the 10 gardening tasks were completed in the morning or last afternoon of Aug. 2012. The weather conditions during the test were an average temperature of (mean $\pm$ SD) 29.6 ± 5.4 °C and a humidity of $76.5 \pm 17.2\%$ (Acuba

CS-201 Digital Hygro-Thermometer; Chosun, Guangdong, China).

EVALUATION OF THE METABOLIC COSTS OF GARDENING TASKS. To measure the metabolic costs of gardening tasks, in terms of oxygen uptake, energy expenditure, and MET, each child wore a portable telemetric calorimeter (K4b²; Cosmed, Rome, Italy) that consists of a portable telemetric transmitter, facemask, flow meter, gas analyzer, receiver, and temperature probe (HR-TEMP). The K4b² is a portable system and is useful for measuring outdoor activities. It has validity and accuracy equal to those of the Douglas bag method, which is generally considered to be the most accurate means of indirect calorimetry but is impractical in outside laboratory settings (Doyon et al., 2001; Kawakami et al., 1992; McLaughlin et al., 2001). The children respired into the facemask during the entire test session to allow measurement of their oxygen uptake, and the data were continuously recorded with individual points representing averaged 3-s intervals. For collection of heart rate data while gardening, the children wore a heart rate monitor (Polar T 31; FitMed, Kempele, Finland) under their breast.

Weight, body composition [fat (grams), lean mass (grams), and percent fat], and height without shoes were measured by a body fat analyzer (ioi 353; Jawon Medical, Gyeongsan, South Korea) and an anthropometer (Ok7979; Samhwa, Seoul, South Korea), which is a well-used height measurement tool. Weight and height data were used to calculate body mass index {body mass index = [weight (kilograms)]/[height (meters)]²}. On the first visit, before starting the first test session, the children sat on a chair for 5 min for measurement of their resting metabolic rate and heart rate. The age-adjusted maximum heart rate was calculated by the equation $208 - 0.7 \times \text{age}$ (Tanaka et al., 2001). Age-adjusted heart rate presents basic information for subjects in studies about metabolic costs of activities (Gunn et al., 2005). Maximum heart rate is the highest number of times heart can contract in 1 min and it is the most useful tool for determining training intensities because it can be measured or predicted for individuals (Atwal et al., 2002).

DATA ANALYSIS. Descriptive information was managed using Excel

Table 1. Description of 10 gardening tasks performed by children aged 11 to 13 years in a study to determine exercise intensities of gardening tasks.

Gardening tasks	Descriptions ^a	Garden tools used ^a
Digging	Digging a garden plot (1.5 × 2 m). Loosening soils in the garden plot. Some movement was required whenever children finished an area.	A shovel (0.7 kg)
Raking	Raking a garden plot (1.5 × 2 m) by slight bending motion. Some movement was required whenever children finished an area.	A rake fork (0.3 kg)
Weeding	Weeding in a grassy area by bending or squatting by hands. Whenever children finished an area, some movement was required.	
Mulching	Mulching with straw around lettuce (<i>Lactuca sativa</i>) in the garden plot (1.5 × 2 m) by bending or squatting motion that was previously prepared. Whenever children needed straw, some movement was required. A bundle of straws were placed right next to the garden plot.	
Hoeing	Hoeing a garden plot (1.5 × 2 m) by squatting motion. Loosening soils in the garden plot. Some movement was required whenever children finished an area.	A hand hoe (0.3 kg)
Sowing seeds	Digging a row, sowing bean (<i>Phaseolus vulgaris</i>) seeds, and covering them with soil by squatting motion. Some movement was required whenever the children needed to make another row for sowing seeds in the garden plot.	A hand trowel (0.1 kg)
Harvesting	Harvesting lettuce and korean sesame leaf (<i>Perilla frutescens</i> var. <i>crispa</i>) planted in a garden plot (5 × 9 m) by bending and stretching arms to pick up the produce and then put it in a bucket. Some movement was required to move to next plants for harvesting.	
Watering	Watering the garden plots (4 × 18 m). Walking with a hose for watering in the garden plot.	A hose
Mixing growing medium	Mixing growing medium (7 peatmoss:3 perlite) in a bucket (50 cm diameter, 15 cm tall) by hand. Water was added by a watering can. The motions such as turning and rubbing growing medium were repeatedly performed while the bucket was standing on a table (0.4 × 0.3 × 0.6 m).	A watering can (1.8 kg)
Planting transplants	Transplanting lettuce into a garden plot (1.5 × 2 m) with squatting motion. Pulling out a transplant from a tray, digging a hole by a hand trowel, planting the plant, and covering with soil around the plant. Some movement was required when children finished an area.	A hand trowel (0.1 kg)

^a1 m = 3.2808 ft, 1 cm = 0.3937 inch, 1 kg = 2.2046 lb.

(Office 2007; Microsoft Corp., Redmond, WA). A one-way analysis of variance (ANOVA) F test was conducted to compare the means of metabolic cost parameters such as oxygen uptake, energy expenditure, MET, and heart rate for the 10 gardening tasks at $P < 0.05$ using SPSS (version 18 for Windows; IBM, Armonk, NY). When the results of the ANOVA test were statistically significant, Scheffé posthoc test was conducted to determine where differences between the means of metabolic cost parameters at $P < 0.05$. Data for the first 10 s were deleted to compensate for the time required to walk to the garden plot and start a gardening task.

Results and discussion

Seventeen Korean children aged 11 to 13 years and in the normal range for body mass index [(mean ± SD) $21.6 \pm 4.0 \text{ kg} \cdot \text{m}^{-2}$] participated in this study (Table 2). The 10 common gardening tasks performed by the

children were moderate- to high-intensity physical activities (4.3 ± 0.5 to 6.6 ± 1.6 MET) (Table 3) (Norton et al., 2010; Pate et al., 1995). Digging (6.6 ± 1.6 MET) and raking (6.2 ± 1.5 MET) were high-intensity physical activities for the children, and digging was more intense than the other gardening tasks performed in this study ($F = 8.62$, $P < 0.0001$). Weeding (5.8 ± 1.1 MET), mulching (5.5 ± 1.3 MET), hoeing (5.3 ± 0.7 MET), sowing seeds (5.0 ± 1.1 MET), harvesting (4.8 ± 0.6 MET), watering (4.6 ± 1.1 MET), mixing growing medium (4.3 ± 0.6 MET), and planting transplants (4.3 ± 0.5 MET) were moderate-intensity physical activities. The tasks such as watering and mixing growing medium were less intense than the other gardening tasks performed in this study ($F = 8.62$, $P < 0.0001$). There was no difference for exercise intensity of various gardening tasks tested between boys and girls in this study (data not shown).

The exercise intensity associated with gardening tasks may differ because of age, gender, body mass, functional capacity, kinds of garden tools, methods of gardening, or garden conditions (Abadi et al., 2010; Ainsworth et al., 2000; Norton et al., 2010; Park et al., 2011). When comparing the exercise intensities of gardening tasks, the MET values are found to differ according to age group. Younger individuals showed higher MET values for most of the gardening tasks, in comparison with adults in their twenties or older adults over 65 years of age. In previous studies, the average range of MET values of the same gardening tasks that were performed by Korean adults in their twenties (3.5 ± 0.5 to 6.3 ± 1.2 MET) were slightly lower than in children (Park et al., 2012a) (Table 3). With regard to older adults, common gardening tasks were judged as low- to moderate-intensity physical activities in American (1.6 ± 0.5 to 3.6 ± 0.8 MET) or Korean adults

(1.7 ± 0.4 to 4.5 ± 1.2 MET) over 65 years of age (Park et al., 2008a, 2011, 2012b), and the average range of MET for gardening tasks was lower than those in children (Table 3) or adults in their twenties (Park et al., 2012a). The exercise intensity of typical physical activities may also differ due to age. Harrell et al. (2005) reported that the METs values for walking (3.5 mph) was 7.02 MET in children aged 8 to 11 years and 5.78 MET in the children 13 to 15 years. Running

(5 mph) was 11.0 MET in the children aged 8 to 11 years and 10.35 MET in the children 13 to 15 years (Harrell et al., 2005).

Among the various common gardening tasks, digging was more intense when compared with the other gardening tasks in adults in their twenties, older adults over 65 years, and children aged 11 to 13 years (Table 3) (Park et al., 2008a, 2011, 2012b). Tasks such as raking, mulching, and hand weeding were low- to

moderate-intensity physical activities in older adults over 65 years of age (Park et al., 2008a, 2011), but these were moderate- to high-intensity physical activities in adults in their twenties (Park et al., 2012a) and children between 11 and 13 years old in this study (Table 3). Transplanting plants, mixing soil, and filling containers with soil were low-intensity physical activities in older adults (Park et al., 2008a, 2011) and moderate-intensity activities in adults in their twenties (Park et al., 2012a) and children (Table 3). Sowing seeds, watering using a watering can or hose, and harvesting produce were low-intensity activities in older adults (Park et al., 2011) and moderate-intensity activities in adults in their twenties (Park et al., 2012a) and children (Table 3). The gardening tasks that actively used the upper and lower body with a heavy tool were more intense than the tasks that mainly used the upper body, involved standing or sitting, and involved little movement during the task.

In conclusion, this is unique research-based data for MET of various gardening tasks in children by using a portable measurement tool with a high accuracy and validity. The results support the anecdotal evidence for gardening as a physical activity for health in children. Children can use gardening to meet the physical activity recommendation for health benefits (at least 60 min of moderate to vigorous-intensity physical activity). Gardening interventions may lead to the same health benefits as other types of physical activities. Moreover, in

Table 2. Descriptive information of children whom participated in the study to determine exercise intensities of selected gardening tasks.

Variable	Children (N = 17)	
	Mean	SD
Age (years)	12.4	0.7
Height (cm) ^z	146.9	4.8
Body weight (kg) ^y	45.8	11.0
Body composition		
Body mass index (kg·m ⁻²)	21.6	4.0
Fat (g) ^y	9,587.5	6,336.9
Lean (g) ^y	34,706.3	4,067.2
Percent fat (%) ^y	19.0	8.8
Resting metabolic rate ^x		
VO ₂ (mL·kg ⁻¹ ·min ⁻¹) ^w	7.7	1.5
Energy expenditure (kJ·kg ⁻¹ ·h ⁻¹) ^v	9.3	1.8
Resting metabolic equivalents (MET) ^u	2.2	0.4
Resting heart rate (HR) (beats/min) ^x	97.7	11.5
Age-adjusted HRmax (beats/min) ^t	199.4	0.5

^zHeight without shoes was measured by an anthropometer (Ok7979; Samhwa, Seoul, South Korea); 1 cm = 0.3937 inch.

^yMeasured by a body fat analyzer (ioi 353; Jawon Medical, Gyeongsan, South Korea); 1 kg = 2.2046 lb, 1 kg·m⁻² = 0.2048 lb/ft², 1 g = 0.0353 oz.

^xMeasured by a portable calorimetric instrument (K4b²; Cosmed, Rome, Italy) and a radiotelemetry monitor (Polar T 31; FitMed, Kempele, Finland). The subject sat on a chair for a 5-min rest.

^wOxygen uptake; 1 mL·kg⁻¹ = 0.0277 inch³/lb.

^v1 kJ·kg⁻¹ = 0.1083 calorie/lb.

^u1 MET = 3.5 mL·kg⁻¹·min⁻¹ oxygen (Norton et al., 2010) = 0.0969 inch³/lb oxygen per minute.

^tAge-adjusted maximum HR = 208 - 0.7 × age (Tanaka et al., 2001).

Table 3. Metabolic measurements of children aged 11 to 13 years whom participated in the study to determine exercise intensities of selected gardening tasks.

Gardening task	Mean (SD)				
	Metabolic equivalents (MET) ^z	VO ₂ (mL·kg ⁻¹ ·min ⁻¹) ^y	Heart rate (beats/min)	Energy expenditure (kJ·kg ⁻¹ ·h ⁻¹) ^x	HRmax (%) ^w
Digging	6.6 (1.6) a ^v	23.0 (5.5) a	134.3 (16.0) a	27.4 (6.7) a	36.0 (11.8) a
Raking	6.2 (1.5) ab	21.7 (5.4) ab	135.8 (13.0) a	26.2 (6.5) ab	37.7 (9.8) a
Weeding	5.8 (1.1) abc	20.2 (4.0) abc	123.9 (14.3) a	24.1 (4.7) abc	25.7 (11.9) ab
Mulching	5.5 (1.3) abc	19.2 (4.7) abc	121.6 (16.4) a	23.0 (5.3) abc	24.6 (13.7) ab
Hoeing	5.3 (0.7) abc	18.6 (2.6) abc	124.9 (17.0) a	22.5 (3.1) abc	26.1 (13.4) ab
Sowing seeds	5.0 (1.1) bc	17.4 (3.9) bc	120.1 (16.6) a	21.0 (4.6) abc	22.5 (13.4) ab
Harvesting	4.9 (0.6) bc	17.0 (2.1) bc	119.6 (12.6) a	20.7 (3.0) bc	23.5 (8.6) ab
Watering	4.6 (1.1) c	16.1 (3.7) c	121.5 (9.9) a	19.4 (4.3) c	23.1 (10.5) ab
Mixing growing medium	4.4 (0.6) c	15.3 (2.2) c	119.4 (15.1) a	18.6 (3.4) c	26.0 (10.1) ab
Planting transplants	4.3 (0.5) c	15.0 (1.7) c	113.7 (12.4) a	18.1 (1.8) c	16.5 (13.3) b

^z1 MET = 3.5 mL·kg⁻¹·min⁻¹ oxygen (Norton et al., 2010) = 0.0969 inch³/lb oxygen per minute.

^yOxygen uptake; 1 mL·kg⁻¹ = 0.0277 inch³/lb.

^x1 kJ·kg⁻¹ = 0.1083 calorie/lb.

^wMaximum heart rate (HRmax) = 208 - 0.7 × age (Tanaka et al., 2001). Age-adjusted HRmax was 207.6 ± 0.7 beats/min (Table 2).

^vMeans sharing a common letter are not significantly different by Scheffé test at *P* = 0.05.

comparison with indoor activities, outdoor activities such as gardening may help to maintain motivation for participating in an exercise intervention and make children physically active (Bird, 2004; Department of Health, 2004; Park et al., 2008a, 2009). Seasonal variations and plant growth cycles also contribute to maintaining motivation for participating in a gardening exercise intervention (Park et al., 2008b).

It would be interesting to compare the exercise intensity of gardening activities with formal physical activities such as walking or jogging. Future studies need to determine the effect of a gardening exercise program on promoting the health conditions of children and making them physically active. Moreover, the MET data for various gardening activities in children can be useful information when a garden-based therapeutic intervention is designed for the children with low levels of physical ability for improving physical functional health conditions.

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