The Metabolic Costs of Gardening Tasks in Children

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ADDitional index words. Cosmed K4b², horticultural therapy, METs, physical activity, socio-horticulture

SUMmary. The metabolic cost of 10 gardening tasks was measured in children to determine the exercise intensities associated with these tasks. Seventeen children (mean ± 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), 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 (Tavares 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; Recs 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 Manus, 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 Gurantz, 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; Mabic and Baker, 1996; Smith and Motsenbocker, 2005) and eating habits, including increased fruit and vegetable intake (Lineberger and Zajicek,

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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 ± 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 ± SD) 29.6 ± 5.4 °C and a humidity of 76.5 ± 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 T31; 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 (iio 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 \(\text{BMI} = \frac{\text{weight (kilograms)}}{\text{height (meters)}^2}\). 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.

<table>
<thead>
<tr>
<th>Gardening tasks</th>
<th>Descriptions*</th>
<th>Garden tools used*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging</td>
<td>Digging a garden plot (1.5 × 2 m). Loosening soils in the garden plot. Some movement was required whenever children finished an area.</td>
<td>A shovel (0.7 kg)</td>
</tr>
<tr>
<td>Raking</td>
<td>Raking a garden plot (1.5 × 2 m) by slight bending motion. Some movement was required whenever children finished an area.</td>
<td>A rake fork (0.3 kg)</td>
</tr>
<tr>
<td>Weeding</td>
<td>Weeding in a grassy area by bending or squatting by hands. Whenever children finished an area, some movement was required.</td>
<td></td>
</tr>
<tr>
<td>Mulching</td>
<td>Mulching with straw around lettuce (Lactuca sativa) 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.</td>
<td></td>
</tr>
<tr>
<td>Hoeing</td>
<td>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.</td>
<td>A hand hoe (0.3 kg)</td>
</tr>
<tr>
<td>Sowing seeds</td>
<td>Digging a row, sowing bean (Phaseolus vulgaris) 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.</td>
<td>A hand trowel (0.1 kg)</td>
</tr>
<tr>
<td>Harvesting</td>
<td>Harvesting lettuce and korean sesame leaf (Perilla frutescens var. crispa) 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.</td>
<td></td>
</tr>
<tr>
<td>Watering</td>
<td>Watering the garden plots (4 × 18 m). Walking with a hose for watering in the garden plot.</td>
<td>A hose</td>
</tr>
<tr>
<td>Mixing growing medium</td>
<td>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).</td>
<td>A watering can (1.8 kg)</td>
</tr>
<tr>
<td>Planting transplants</td>
<td>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.</td>
<td>A hand trowel (0.1 kg)</td>
</tr>
</tbody>
</table>

*1 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 ± 4.0 kg 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...
Table 2. Descriptive information of children whom participated in the study to determine exercise intensities of selected gardening tasks.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Children (N = 17)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>12.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>146.9</td>
<td>4.8</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>45.8</td>
<td>11.0</td>
</tr>
<tr>
<td>Body composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg m⁻²)</td>
<td>21.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>9587.5</td>
<td>6336.9</td>
</tr>
<tr>
<td>Lean (g)</td>
<td>34706.3</td>
<td>4067.2</td>
</tr>
<tr>
<td>Percent fat (%)</td>
<td>19.0</td>
<td>8.8</td>
</tr>
<tr>
<td>Resting metabolic rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO₂ (mL kg⁻¹ min⁻¹)</td>
<td>7.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Energy expenditure (kJ kg⁻¹ h⁻¹)</td>
<td>9.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Resting metabolic equivalents (MET)</td>
<td>2.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Resting heart rate (HR) (beats/min)</td>
<td>97.7</td>
<td>11.5</td>
</tr>
<tr>
<td>Age-adjusted HRmax (beats/min)</td>
<td>199.4</td>
<td>0.5</td>
</tr>
</tbody>
</table>

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

bMeasured 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.

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

VO₂ measured by a portable calorimetry instrument (K4b²; Cosmed, Rome, Italy).

wOxygen uptake; 1 mL VO₂ = 0.0277 inch³/lb.

x1 MET = 3.5 mL kg⁻¹ min⁻¹ oxygen (Norton et al., 2010) = 0.0969 inch³/lb oxygen per minute.

y1 MET = 3.5 mL kg⁻¹ min⁻¹ oxygen (Norton et al., 2010) = 0.0969 inch³/lb oxygen per minute.

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

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

<table>
<thead>
<tr>
<th>Gardening task</th>
<th>Metabolic equivalents (MET)</th>
<th>VO₂ (mL kg⁻¹ min⁻¹)</th>
<th>Heart rate (beats/min)</th>
<th>Energy expenditure (kJ kg⁻¹ h⁻¹)</th>
<th>HRmax (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging</td>
<td>6.5 (1.6) a</td>
<td>23.0 (5.5) a</td>
<td>134.3 (16.0) a</td>
<td>27.4 (6.7) a</td>
<td>36.0 (11.8) a</td>
</tr>
<tr>
<td>Raking</td>
<td>6.3 (1.5) ab</td>
<td>21.7 (5.4) ab</td>
<td>135.8 (13.0) a</td>
<td>26.2 (6.5) ab</td>
<td>37.7 (9.8) a</td>
</tr>
<tr>
<td>Weeding</td>
<td>5.8 (1.1) abc</td>
<td>20.2 (4.0) abc</td>
<td>123.9 (14.3) a</td>
<td>24.1 (4.7) abc</td>
<td>25.7 (11.9) ab</td>
</tr>
<tr>
<td>Mulching</td>
<td>5.5 (1.3) abc</td>
<td>19.2 (4.7) abc</td>
<td>121.6 (16.4) a</td>
<td>23.0 (5.3) abc</td>
<td>24.6 (13.7) a</td>
</tr>
<tr>
<td>Hoeing</td>
<td>5.3 (0.7) abc</td>
<td>18.6 (2.6) abc</td>
<td>124.9 (17.0) a</td>
<td>22.5 (3.1) abc</td>
<td>26.1 (12.4) a</td>
</tr>
<tr>
<td>Sowing seeds</td>
<td>5.0 (1.1) bc</td>
<td>17.4 (3.9) bc</td>
<td>120.1 (16.6) a</td>
<td>21.0 (4.6) abc</td>
<td>22.5 (13.4) a</td>
</tr>
<tr>
<td>Harvesting</td>
<td>4.9 (0.6) bc</td>
<td>17.0 (2.1) bc</td>
<td>119.6 (12.6) a</td>
<td>20.7 (3.0) bc</td>
<td>23.5 (8.6) a</td>
</tr>
<tr>
<td>Watering</td>
<td>4.6 (1.1) c</td>
<td>16.1 (3.7) c</td>
<td>121.5 (9.9) a</td>
<td>19.4 (4.3) c</td>
<td>23.1 (10.5) ab</td>
</tr>
<tr>
<td>Mixing growing medium</td>
<td>4.4 (0.6) c</td>
<td>15.3 (2.2) c</td>
<td>119.4 (15.1) a</td>
<td>18.6 (3.4) c</td>
<td>26.0 (10.1) ab</td>
</tr>
<tr>
<td>Planting transplants</td>
<td>4.3 (0.5) c</td>
<td>15.0 (1.7) c</td>
<td>113.7 (12.4) a</td>
<td>18.1 (1.8) c</td>
<td>16.5 (13.3) b</td>
</tr>
</tbody>
</table>

a1 MET = 3.5 mL kg⁻¹ min⁻¹ oxygen (Norton et al., 2010) = 0.0969 inch³/lb oxygen per minute.

b1 MET = 3.5 mL kg⁻¹ min⁻¹ oxygen (Norton et al., 2010) = 0.0969 inch³/lb oxygen per minute.

c1 MET = 3.5 mL kg⁻¹ min⁻¹ oxygen (Norton et al., 2010) = 0.0969 inch³/lb oxygen per minute.

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

*Means sharing a common letter are not significantly different by Scheffe 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.

**Literature cited**


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