

Research Report

Comparison of the Metabolic Costs of Gardening and Common Physical Activities in Children

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Abstract: This study investigated the exercise intensity and energy expenditure involved in two gardening activities (planting transplants and sowing seeds in a garden plot) and four common physical activities (running, skipping rope, walking, and throwing a ball) in children. Eighteen children aged 11 to 13 years (mean age, 12.3 ± 0.7 years) participated in this study. The children made two visits to a high tunnel in Cheongju, Chungbuk, South Korea and performed randomly selected activities. Each activity was performed for 10 min, with a 5-min rest period between activities. The children wore a Cosmed K4b² (Cosmed K4b²; Cosmed, Rome, Italy), which is a portable calorimetric monitoring system, to measure indicators of metabolic cost such as oxygen uptake and energy expenditure. The children's heart rates during the activities were measured by radiotelemetry (Polar T 31; FitMed, Kempele, Finland). We found that the two gardening and four physical activities performed by the 11-13 years old children in this study were moderate- to high-intensity physical activities [i.e., 5.4 ± 0.7 to 9.1 ± 1.4 metabolic equivalents (METs)]. Running (9.1 ± 1.4 METs) and skipping rope (8.8 ± 1.1 METs) were high-intensity physical activities, whereas walking (6.1 ± 0.9 METs), planting transplants (5.8 ± 1.1 METs), throwing a ball (5.6 ± 1.1 METs), and sowing seeds (5.4 ± 0.7 METs) were moderate-intensity physical activities. Running and skipping rope were significantly more intense than the other activities ($P < 0.0001$). The gardening tasks such as planting transplants and sowing seeds in a garden plot showed similar exercise intensities and energy costs as walking and throwing a ball. This study indicates that gardening can be used as a physical activity intervention to provide health benefits similar to more common physical activities such as walking and running.

Additional key words: Cosmed K4b², energy expenditure, exercise intensity, horticultural therapy, socio-horticulture

Introduction

The Centers for Disease Control and Prevention recommends at least 60 min of moderate- to high-intensity physical activity per day on most days of the week in order to attain health benefits in children (Salmon and Shilton, 2004; Strong et al., 2005). Regular physical activity in children decreases adiposity, lowers blood pressure, improves musculoskeletal and cardiovascular health, and increases bone density (Dietz, 1998; Ekeland et al., 2005; Fraser et al., 1983; Parfitt and Eston, 2005; Strong et al., 2005). Physical activity also improves psychological health, e.g., increases self-esteem, decreases anxiety and stress, and

increases feelings of wellbeing (Dietz, 1998; Horst et al., 2007; Strong et al., 2005; Wipfli et al., 2008). Moreover, participation in physical activity during childhood can not only reduce the immediate risk for conditions such as diabetes, obesity, and cardiovascular diseases but also decrease the future risk for chronic diseases in adulthood (Twisk et al., 1997; Williams et al., 2002).

Despite the many health benefits of physical activity, children generally maintain sedentary lifestyles with low levels of physical activity (Warren et al., 2010; WHO, 2010). This trend towards physical inactivity and sedentary lifestyles is increasing the prevalence of obesity and risk factors for chronic diseases in adulthood (Malina, 2001; Telama

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et al., 1997; U.S. Department of Health and Human Services, 1996; Wittmeier et al., 2008).

The major reasons reported for children's avoidance of physical activity are a preference for indoor activities such as watching television and playing video and computer games, time constraints, lack of motivation, hesitation caused by perceived incompetence or lack of skill, lack of resources, and insufficient social support from parents and peers (Burdette and Whitaker, 2005; Gordon-Larsen et al., 2009; Norman et al., 2005; O'Dea, 2003; Rees et al., 2006; Spear et al., 2007; Taveras et al., 2007). Therefore, effective interventions to encourage participation in regular physical activity are required. Enjoyment and fun are especially crucial factors for maintaining motivation and interest in participation in children (Baranowski et al., 2008; Borra et al., 1995; Brown et al., 2013; Epstein et al., 2007; Mellecker and McManus, 2008).

Gardening is a hands-on task at all stages, from planning the garden to planting seeds or transplants, harvesting produce, and publicizing the garden in the community (Lekies and Sheavly, 2007). Gardening exposes children to seasonal variation and the plant growth cycle (Park et al., 2008). These dynamic activities in the garden can be fun and exciting for children and thus help to maintain their motivation to participate in a gardening intervention. Moreover, plants in a garden need to be tended regularly (Park et al., 2008), which helps to promote a physically active lifestyle. In addition, school gardening with incorporation of science and math into the activities has also been used as a teaching tool for improving academic achievement (Braun et al., 1989; Kutsunai, 1994; Pigg et al., 2006).

In adults and older adults, gardening tasks have been determined to be low- to high-intensity physical activities in terms of the health benefits that they provide (Park et al., 2011, 2012). Such common gardening tasks as digging, raking, planting, and harvesting were moderate- to high-intensity physical activities (3.5 ± 0.5 to 6.3 ± 1.2 METs) when performed by people in their 20s (Park et al., 2012) but low- to moderate-intensity physical activities (1.7 ± 0.4 to 4.5 ± 1.2 METs) when performed by older adults aged 65 years (Park et al., 2011). However, there is insufficient information to determine whether gardening is a health-promoting physical activity, especially in children.

Therefore, this study was performed to compare the exercise intensity and energy expenditure of gardening activities (planting transplants and sowing seeds) with those of common physical activities (running, skipping rope, walking, and throwing a ball) in children in order to determine whether gardening can be utilized as a health-promoting

physical activity in elementary school children.

Materials and Methods

Subjects

Eighteen Korean children aged 11 to 13 years were recruited from the community in Cheongju, Chungbuk, South Korea. A recruiting flyer containing a description of the study and its requirements was posted at churches, community centers, and residential areas in Cheongju. Recruitment was also conducted by word of mouth. The inclusion criteria were age 11 to 13 years, no current diseases, and the parents' informed consent (documented by a signed form). The testing schedule for each child was decided by phone with the child or their parents at least one week before the start of the first test session; the study and its requirements were also described during this phone call. The children were required not to eat a heavy meal or perform physical activity for at least 12 h before the testing. They were also required to wear clothes, shoes, and gloves appropriate for gardening. As an incentive, each child received US \$10 at the completion of the entire testing program.

Experimental Procedures and Physical Activities Performed

The participants performed two gardening activities (planting transplants and sowing seeds) and four common physical activities (running, skipping rope, throwing a ball, and walking) in a high tunnel (14×6 m) in Cheongju, Chungbuk, South Korea (Table 1). The children visited the experimental site and performed four physical activities and two gardening activities in a random order that was determined by drawing lots. Each of the activities was performed for 10 min with a 5-min rest break between activities. Although preliminary studies (Park et al., 2011, 2012) found that a 5-min activity period was sufficient to obtain metabolic measurements, a 10-min period of each activity was used because activities performed for at least 10 min at a time contribute to the health benefits of physical activity (<http://www.cdc.gov/physicalactivity/everyone/guidelines/olderadults.html>). All activities were performed continuously for 10 min unless a child could not continue. Some children took short breaks during the skipping rope activity. The time for each activity was monitored throughout the entire session using a stopwatch.

All the activities were completed in Aug. 2012. The average temperature was $29.6 \pm 5.4^\circ\text{C}$ and the average humidity was $76.5 \pm 17.2\%$ in the high tunnel during the test (Digital Hygro-Thermometer, Model Acuba CS-201, Chosun, Guangdong, China).

Table 1. Descriptions of the gardening and physical activities that were performed by the children.

Activity ^z	Description
Running	Running in large circles
Skipping rope ^y	Jumping rope with a 0.1-kg rope
Walking	Walking in large circles
Throwing a ball	Each child repeatedly exchanged a 0.3-kg volleyball with a researcher over a distance of 4 m
Planting transplants	1) Digging a garden plot (1.5 × 2 m) with a 0.7-kg shovel for 3-min, 2) Raking the garden with a 0.9-kg rake for 3-min, 3) Planting transplants in the garden for 3-min, 4) Watering with a hose for 1-min.
Sowing seeds	1) Cultivating with a 0.3-kg hand hoe for 3-min, 2) Digging furrows with a 0.1-kg hand trowel for 3-min, 3) Sowing bean seeds (<i>Fabaceae</i>) in the furrows for 3-min, 4) Watering with a hose for 1-min.

^zEach activity was performed continuously for 10 min in a high tunnel (14 × 6 m) in Cheongju, Chungbuk, South Korea. All activities were performed continuously for 10 min unless a child could not continue.

^ySome children took a short break during the skipping rope activity.

Measurements

Each child wore a portable indirect calorimeter, the Cosmed K4b² (Cosmed K4b²; Cosmed, Rome, Italy), which measures oxygen uptake to determine the METs values of physical activities. The children continuously respired into the facemask to measure their oxygen uptake (VO₂) throughout each entire test session. The Cosmed K4b² provides a convenient way to measure the energy costs of outdoor activities such as running and gardening, and its validity and accuracy equal to those of the Douglas bag method, which is generally considered to be the most accurate indirect calorimetry technique (Doyon et al., 2001; Kawakami et al., 1992; McLaughlin et al., 2001). Each child also wore a heart rate monitor under the pectoral region, and the heart rate data were measured continuously throughout each entire test session by radiotelemetry (Polar T 31; FitMed, Kempele, Finland).

The descriptive data, such as height, weight, body composition, resting metabolic rate, and resting heart rate, were obtained before the start of the first test session (Table 2). Weight and body composition were measured using a body fat analyzer (ioi 353; Jawon Medical, Gyeongsan, South Korea), and height was measured using an anthropometer (Ok7979; Samhwa, Seoul, South Korea). Resting metabolic rate and heart rate were measured using a portable telemetric calorimeter (Cosmed K4b²) and heart rate monitor (Polar T 31) while the child sat quietly on a chair for 5 min. Body mass index was calculated from the weight and height data [body mass index = weight (kilograms)/(height (meters)²]. Age-adjusted maximum heart rate was calculated as 208 - 0.7 × age (Tanaka et al., 2001).

Table 2. Descriptive characteristics of the children (N = 18) who participated in this study to investigate the exercise intensities and energy costs of gardening and common physical activities in children.

Variable	Mean	SD
Age (years)	12.3	0.7
Height (cm)	148.1	7.8
Body weight (kg) ^z	46.2	12.4
Body composition		
Body mass index (kg·m ⁻²)	21.2	4.2
Fat (g) ^z	9529.4	6416.5
Lean (g) ^z	35,058.8	5979.1
Percent fat (%) ^z	18.5	9.1
Resting metabolic rate ^y		
VO ₂ (mL·kg ⁻¹ ·min ⁻¹)	7.2	1.2
Energy expenditure (kJ·kg ⁻¹ ·h ⁻¹)	8.7	1.4
Resting metabolic equivalents (METs)	2.1	0.3
Resting heart rate (HR) (beats/min) ^x	92.1	10.6
Age-adjusted HRmax (beats/min) ^w	199.4	0.5

^zMeasured using a body fat analyzer (ioi 353).

^yMeasured using a portable calorimetric instrument (Cosmed K4b²) while the child sat quietly on a chair for 5 min.

^xMeasured using a radiotelemetry monitor (Polar T 31) while the child sat quietly on a chair for 5 min.

^wAge-adjusted maximum heart rate (HRmax) = 208 - 0.7 × age.

Data Analysis

The descriptive data were manipulated using Excel (Microsoft Office 2002; Microsoft Corp., Redmond, WA). For each activity,

the data from the first 10 s were deleted to compensate for the time required to walk to the garden plot or activity location before the start of the activity. Duncan's multiple range test was used to compare the mean metabolic rates for the two gardening and four physical activities with a significance level of $P < 0.05$ using the Statistical Analysis System (SAS Version 9 for Windows, SAS Institute, Inc., Cary, NC).

Results

Characteristics of the Subjects

Eighteen children (13 males and 5 females) with a mean age of 12.3 ± 0.7 years and a mean body mass index of $21.2 \pm 4.2 \text{ kg}\cdot\text{m}^{-2}$ participated in this study (Table 2).

Metabolic Costs of Gardening and Common Physical Activities

The two gardening and four common physical activities performed by the 11-13 years old children in this study were moderate- to high-intensity physical activities (i.e., 5.4 ± 0.7 to 9.1 ± 1.4 METs) (Table 3). Running and skipping rope were high-intensity physical activities (Table 3), whereas walking, planting transplants, throwing a ball, and sowing seeds were moderate-intensity physical activities (Table 3). The dependent variables (METs, oxygen uptake, heart rate, and energy expenditure) differed significantly among the six activities ($F = 63.02$, $p < 0.0001$). Running and skipping rope were more intense than the other activities, whereas sowing seeds was the least-intense activity performed in this study. The exercise intensity and energy cost were similar between the gardening tasks such as planting transplants

and sowing seeds in a garden plot, walking, and throwing a ball (Table 3).

Discussion

In this study, eighteen 11-13 years old (mean 12.3 ± 0.7 years old) children with body mass index values within the normal range performed two gardening and four common physical activities in order to determine the exercise intensities and energy costs of the activities. These activities were moderate- to high-intensity physical activities (5.4 ± 0.7 to 9.1 ± 1.4 METs) (Table 3) when performed by the children. Running and skipping rope, which required active movement of the entire body, were high-intensity physical activities in children. Walking, throwing a ball, planting transplants, and sowing seeds in a garden plot required less oxygen consumption during the activity than did running and skipping rope and were therefore moderate-intensity physical activities in children.

This result concurs with previous research findings. Harrell et al. (2005) determined that walking (4 kph) was a moderate-intensity physical activity when performed by children (i.e., age range 8-12 years: 5.84 METs; age range 13-15 years: 4.95 METs). Walking (5.6 kph) required 7.02 METs and 5.78 METs in the children aged 8-11 years and 13-15 years, respectively (Harrell et al., 2005). Skipping rope and running were high-intensity physical activities in children: Skipping rope required 10.10 METs in children aged 8-12 years and 10.06 METs in children aged 13-15 years (Harrell et al., 2005). The METs values for running (8 kph) were 11.0 METs and 10.35 METs in the children aged 8-11 years and 13-15 years, respectively (Harrell et al., 2005).

Table 3. Metabolic results of gardening activities and common physical activities in children (N = 18).

Activity	Mean (SD)			
	Metabolic equivalents (METs) ^z	Oxygen uptake ^x (mL·kg ⁻¹ ·min ⁻¹)	Heart rate (beats/min)	Energy expenditure (kJ·kg ⁻¹ ·h ⁻¹)
Running	9.1 (1.4) a ^y	31.9 (5.0) a	162.8 (18.8) a	38.8 (6.3) a
Skipping rope	8.8 (1.1) a	30.6 (3.7) a	162.3 (18.2) a	37.7 (4.6) a
Walking	6.1 (0.9) b	21.3 (3.3) b	133.3 (16.8) b	25.4 (4.0) b
Planting transplants	5.8 (1.1) b	20.4 (3.8) b	126.6 (12.3) b	24.7 (4.5) b
Throwing a ball	5.6 (1.1) b	19.6 (3.7) b	130.9 (20.9) b	23.2 (4.5) b
Sowing seeds	5.4 (0.7) b	19.0 (2.6) b	122.9 (12.9) b	22.9 (2.9) b

^z1 metabolic equivalent = $3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

^yMeans with the same letter did not differ significantly according to Duncan's multiple range test with a significance level of $P < 0.05$.

^xVO₂.

In our previous study, various gardening tasks were determined to be moderate- to high-intensity physical activities in children aged 11 to 13 years (Park et al., 2012). Digging (6.6 ± 1.6 METs) and raking (6.2 ± 1.5 METs) were high-intensity physical activities and were the highest-intensity gardening tasks performed in this study (Park et al., 2012). Other gardening tasks, such as weeding (5.8 ± 1.1 METs), mulching (5.5 ± 1.3 METs), hoeing (5.3 ± 0.7 METs), sowing (5.0 ± 1.1 METs), harvesting (4.8 ± 0.6 METs), watering (4.6 ± 1.1 METs), mixing growing medium (4.4 ± 0.6 METs), and planting transplants (4.3 ± 0.5 METs) were moderate-intensity physical activities (Park et al., 2012). Therefore, it is consistent that the gardening activities in this study were determined to be moderate-intensity physical activities, as they consisted of series of tasks, such as digging, raking, planting transplants, sowing, and watering, that were determined to be moderate-intensity physical activities in children aged 11 to 13 years in the previous study (Park et al., 2012).

As gardening is, overall, a moderate-intensity activity, participation in gardening interventions can be expected to provide the health benefits of physical activity, such as reduced risk for chronic diseases. Outdoor activities such as gardening may help subjects to stay motivated to participate in the intervention and better promote physically active lifestyles than doing indoor activities (Bird, 2004; Department of Health, 2009; Park et al., 2008, 2009). The seasonal variation of gardening and the plant growth cycles also contribute to maintaining the motivation to participate in a gardening intervention; furthermore, plants in a garden need regular care (Park et al., 2008), which helps to promote a physically active lifestyle. Moreover, learning gardening skills in childhood may lead to gardening as a leisure-time physical activity in adulthood (Bradley et al., 2000; Lohr and Pearson-Mims, 2005).

In conclusion, this study determined that common gardening tasks such as transplanting and sowing seeds can be considered a form of physical activity similar to other moderate intensity physical activities such as walking and throwing a ball for children aged 11-13.

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