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Karin A. Pfeiffer

Kathryn H. Schmitz

Robert G. McMurray

Margarita S. Treuth

David M. Murray

See next page for additional authors

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Physical Activities in Adolescent Girls Variability in Energy Expenditure

Karin A. Pfeiffer, PhD, **Kathryn H. Schmitz, PhD**, **Robert G. McMurray, PhD**, **Margarita S. Treuth, PhD**, **David M. Murray, PhD**, and **Russell R. Pate, PhD**

From the Department of Exercise Science, Arnold School of Public Health, University of South Carolina (Pfeiffer, Pate), Columbia, South Carolina; Division of Epidemiology, University of Pennsylvania (Schmitz), Philadelphia, Pennsylvania; Department of Exercise and Sports Science, University of North Carolina at Chapel Hill (McMurray), Chapel Hill, North Carolina; Center for Human Nutrition, Johns Hopkins Bloomberg School of Public Health (Treuth), Baltimore, Maryland; and Division of Epidemiology, School of Public Health, The Ohio State University (Murray), Columbus, Ohio

Abstract

Background—Understanding interindividual variability of energy expended in common activities is important for determining precise estimates of energy expenditure in surveillance studies and clinical trials. The purpose of this study was to describe the variability in energy expenditure for selected physical activities among adolescent girls.

Methods—Seventy-four adolescent girls (aged 13 to 14 years) participated in this cross-sectional investigation. Data were collected in 2001 and analyzed in 2004. Energy expenditure was measured by indirect calorimetry for ten activities and during a submaximal cycle ergometer test, which was used to estimate cardiorespiratory fitness. Variability in energy expended for the various activities was expressed by standard deviation, coefficient of variation, and range for three different energy expenditure variables: relative VO_2 (milliliters per kilogram per minute), absolute VO_2 (liters per minute^{-1}), and calculated metabolic rate (kilojoules per minute).

Results—Depending on the expression of energy expenditure, coefficients of variation ranged from a low of 13.2% for climbing stairs to a high of 38.4% for playing a computer game. Some lower-intensity activities were associated with greater variability in energy expenditure. Bicycling showed consistently higher coefficients of variation across expressions of energy expenditure (29.1%, 37.7%, and 33.5% for relative VO_2, absolute VO_2, and calculated metabolic rate, respectively).

Conclusions—Energy expenditure for common activities is highly variable in adolescent girls. The coefficient of variation was higher in some activities of lower intensity, regardless of energy expenditure expression. This variance may influence the evaluation of physical activity interventions, particularly with regard to issues such as a prescribed dose of activity and the statistical power to detect change.

Introduction

The prevalence of overweight and at risk for overweight in children and adolescents now exceeds 30%.[1] Energy imbalance contributes to overweight in children and adolescents, and physical inactivity plays a significant role in energy imbalance.[2] Interventions to prevent or

Address correspondence and reprint requests to: Karin Allor Pfeiffer, PhD, 730 Devine St., Department of Exercise Science, University of South Carolina, Columbia SC 29208. E-mail: kapfeiffer@sc.edu.

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reduce overweight will need to increase physical activity or decrease sedentary behaviors in youth.

Evidence suggests that the amount of energy required to perform physical activities changes with age and pubertal status.[3] However, the variability in energy expenditure for common activities in children and adolescents is unknown. It is important to understand this variability in order to predict the likely response for a given dose of activity, especially for girls, whose physical activity declines steeply during adolescence.[4] The purpose of this study was to describe the variability in energy expenditure of selected activities among adolescent girls.

Methods

Participants in this cross-sectional investigation were 74 girls, aged 13 to 14 years, who were representative of the population of their schools in terms of size and body mass index (BMI). Data were collected in 2001 by investigators in three states (MD, MN, SC) and analyzed in 2004 as preliminary data for the Trial of Activity for Adolescent Girls (TAAG) study. The protocol was approved by each institution's Human Subjects Review Board. Parental consent and participant assent were obtained.

Participants performed ten activities (Table 1), including five during each of two data-collection sessions, completed within 2 weeks, at least 24 hours apart. Each activity (in ascending order of intensity) was performed for 7 minutes, with the exception of rest (15 minutes). The resting measurement took place in a dimly lit room with the participant reclined. Intensities of the other activities were regulated to varying degrees (see Table 1), producing inherent differences in how any given participant performed the activities. Before each visit, the participants fasted for 3 hours in order to limit any effects of digestion on energy expenditure.

Age, race, and ethnicity were self-reported via questionnaire. Height and weight were measured at the first visit according to standard procedures. Expired respiratory gases were collected on a breath-by-breath basis while participants performed the ten activities and during a submaximal cycle ergometer test. Oxygen consumption (VO_2) for all activities was measured using a Cosmed portable metabolic system (K4b2, Rome, Italy). The unit is a lightweight system (925 g) that was worn on the back via a harness. Prior to each measurement session and after any environmental change within a session, the unit was calibrated with standard gases.

Cardiorespiratory fitness (VO_{2max}) was estimated using data from a cycle ergometer (Monark, Model 818E, Varberg, Sweden) test (physical working capacity).[5] Participants rode for at least two 3-minute stages at a cadence of 60 rpm, during which VO_2 and heart rate (HR) data were collected. Trained research assistants recorded heart rate and power output data at the end of each stage, and the test was completed when it was ≥165 beats/minute at the end of a stage. Values were used to develop individual linear regression equations predicting VO_2 for a heart rate of 195. The result was multiplied by 1.17 to account for the nonlinear nature of oxygen uptake at higher workloads in young adolescents.[6–8]

Statistical Analysis

The analyses involved four dependent variables: absolute VO_2 (liters/minute), weight-relative VO_2 (milliliters per kilogram per minute), estimated metabolic rate (kilojoules per minute),[9] and predicted relative intensity (percent predicted VO_{2max}=[VO_2 {activity} − VO_2 {rest}]/[predicted VO_2 {max} − VO_2 {rest}] × 100). Different expressions of energy expenditure were examined in order to highlight the differences due to taking body weight into account. For each girl, breath-by-breath values were first averaged for each 1-minute segment for each activity.

Next, the minute-to-minute values were averaged to calculate a single average value for each girl for each dependent variable and each activity. Minutes 3 to 15 were used for the resting data, and minutes 4 to 7 for the other activities to ensure that energy expenditure data reflected a steady state. The number of subjects differed across activities due to occasional equipment malfunction or the inability of the girls to complete some activities. For each dependent variable, the mean was calculated for each activity, averaging across girls. For the first three dependent variables, the standard deviation, the coefficient of variation (CV, a relative measure of data dispersion compared to the mean), and the range were also calculated across all girls. All analyses were performed using SAS, version 8.2 (SAS Institute, Cary NC, 2001).

Results

Participant characteristics included (mean ± standard deviation [SD]) age (14.1 ± 0.3 years), height (160 ± 6.6 cm), weight (60 ± 15.5 kg); BMI (23.4 ± 5.8 kg/m^2), resting VO_2 (3.8 ± 0.9 ml/kg/min), and predicted VO_{2max} (38.8 ± 9.7 ml/kg/min). Table 2 shows for each activity the mean and standard deviation, coefficient of variation, and range for the three energy expenditure variables. As one would expect, the standard deviations and ranges generally increased as the means and the mean relative intensity of activities increased. However, biking had the highest standard deviations and greatest spread in range values across the three energy expenditure expressions (SDs of 6.25, 0.47, and 8.87 and ranges of 27.1, 2.82, and 52.8, respectively).

The coefficients of variation ranged from a low of 13.2% for climbing stairs to a high of 38.4% for playing a computer game, depending on the expression of energy expenditure (Table 2). Coefficients of variation for computer games, briskly walking, and slowly walking were the most different across expressions of energy expenditure; biking, computer games, and watching TV had consistently higher coefficients of variation than other activities across energy expenditure expressions. In some cases, lower-intensity activities showed higher coefficients of variation. For example, playing computer games was the second-lowest-intensity activity, and it had the third highest coefficient of variation for relative VO_2 and the highest for absolute $VO_2$and metabolic rate. Biking had the highest or second highest coefficient of variation for all expressions of energy expenditure. Some higher-intensity activities showed lower coefficients of variation (e.g., stair climbing).

Discussion

The determination of daily energy expenditure in surveillance studies and the prescription of exercise dose for the treatment and prevention of obesity require an estimation of energy expenditure. This study showed that energy expenditure for common activities is highly variable in adolescent girls. Although researchers have examined means and standard deviations for energy expenditure, few have addressed variability in energy expenditure relative to the mean (i.e., coefficient of variation). One study of girls aged 12 years reported a range of coefficient of variation values from 13% to 18% for five activities,[10] which were lower than the coefficients of variation reported in the current investigation. Participants in the previous study performed treadmill exercise at mechanically regulated speeds, which may have resulted in less variation in energy expenditure than in the current study. Also, energy expenditure was expressed as metabolic equivalents (METs), which likely caused differences between the studies.

The greater relative variability in energy expenditure for lower-intensity activities deserves consideration. Many researchers focus on moderate-to-vigorous physical activity (MVPA), and most guidelines recommend particular doses of MVPA.[11] Little is known about light physical activity in youth. Variability in energy expenditure during sedentary/light-intensity activities may explain the differences in BMI across children who appear to engage in equal amounts of MVPA (possibly due in part to variability in resting energy expenditure). A small difference in energy expenditure during sustained light activity (e.g., the 8.8 vs 23.5 kJ/ min^{-1} for walking slowly) could translate into meaningful differences over time (e.g., 1056 vs 2820 kJ over 2 hours).

These results also suggest other considerations. Biking showed the most variability in energy expenditure, possibly related to variance in riding speed (the gears were not changed); however, researchers monitored the girls' speed. Variability may have been associated with energy expenditure required to move the bike; otherwise, it is not known why biking had the greatest variability. Since biking is a common activity for children and adolescents, this warrants further investigation. This investigation focuses on inter-individual variability; intra-individual variability cannot be addressed using these data. Future research regarding intra-individual variability may be useful to researchers. In addition, the variability in energy expenditure observed in this study suggests that researchers use caution when considering statistical power. If an intervention targets low-intensity activities that have higher variance than expected, the power to detect differences may be diminished.

In summary, energy expenditure varies considerably among girls performing the same activity; an activity that may contribute significantly to daily energy expenditure in some girls will be less effective in others. This is important in light of the fact that standardized values (e.g., METs) are often applied for estimation of energy expenditure when other, more accurate techniques (e.g., regression equations developed for the population of interest) may be more appropriate, depending on the research question. More work is necessary to explore the variability that exists in other populations and the implications of the variability, particularly for individuals who are at risk for or overweight.

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Table 1

Description of activities performed

Physical activity	Description
Rest	Participant reclines and lies still in a quiet environment, while remaining awake.
Television viewing	Participant watches a video while sitting on a comfortable chair without getting up at any time.
Playing computer game	Participant plays a computer game using the arrow keys on the keyboard while sitting on a chair.
Sweeping	Participant uses a broom to sweep confetti continuously to a specified location (and repeats).
Slow walk	Participant walks at 2.5 mph on marked area while being prompted to keep pace with timed distances.
Brisk walk	Participant walks at 3.5 mph on marked area while being prompted to keep pace with timed distances.
Step aerobics	Participant follows an aerobics video with an estimated MET value of 6.0.
Bicycle riding	Participant rides a bicycle outside on a relatively flat surface at 12.0 mph, using cyclometer to keep pace.
Shooting baskets	Participant shoots a girls' size ball at a regulation hoop continuously, including chasing the ball for rebounds.
Stair climbing	Participant climbs a staircase to the beat of a music tape (80 steps/min) without stopping or holding rails (except to balance).
Running	Participant runs at 5.0 mph on marked area while being prompted to keep pace with timed distances.

Table 2

Energy expenditure by activity

Activity	Mean ± SD (ml/kg/min)	Coefficient of variation (%)	Range	Mean ± SD (L/min)	Coefficient of variation (%)	Range	Mean ± SD (kJ/min)	Coefficient of variation (%)	Range	Mean % predicted
Rest	3.8 ± 0.93	24.3	2.1–6.6	0.23 ± 0.06	26.5	0.10–0.36	4.55 ± 1.21	26.6	2.1–7.2	0
Watching TV	3.9 ± 0.94	24.0	2.3–6.2	0.23 ± 0.06	25.2	0.12–0.35	4.56 ± 1.16	25.5	2.3–7.2	0.52
Computer game	4.0 ± 0.87	21.8	2.5–6.2	0.24 ± 0.09	38.3	0.12–0.88	4.91 ± 1.89	38.4	2.4–17.6	1.00
Sweeping	11.0 ± 2.17	19.7	6.5–17.3	0.65 ± 0.17	26.4	0.36–1.04	13.1 ± 3.48	26.6	7.3–21.2	21.79
Stairs	24.4 ± 3.21	13.2	16.6–31.9	1.45 ± 0.32	22.2	0.87–2.21	30.0 ± 7.08	23.6	17.5–46.3	62.54
Slow walk	11.6 ± 1.80	15.5	8.2–16.4	0.70 ± 0.18	26.3	0.42–1.18	14.0 ± 3.68	26.2	8.8–23.5	24.16
Brisk walk	15.6 ± 2.31	14.8	9.5–21.7	0.94 ± 0.26	27.2	0.41–1.80	19.1 ± 5.16	27.0	8.6–36.7	36.97
Shooting baskets	24.3 ± 4.84	19.9	14.8–35.6	1.43 ± 0.28	19.6	0.90–2.31	29.0 ± 5.69	19.6	18.0–47.0	59.71
Aerobics	21.2 ± 3.83	18.1	13.7–30.4	1.24 ± 0.31	24.6	0.73–2.11	25.1 ± 6.30	25.1	14.3–42.9	52.68
Bicycle	21.5 ± 6.25	29.1	6.0–33.1	1.26 ± 0.47	37.7	0.15–2.97	26.5 ± 8.87	33.5	3.1–55.9	54.67
Running	29.5 ± 5.02	17.0	14.9–39.5	1.70 ± 0.36	20.9	0.98–2.71	35.5 ± 7.13	20.1	22.6–56.5	73.34

kJ/min/, kilojoules per minute; L/min, liters (of oxygen) per minute; ml/kg/min, milliliters (of oxygen) per kilogram body weight per minute; % predicted VO_2 max, predicted maximal oxygen uptake.