The Short Questionnaire to Assess Health-Enhancing (SQUASH) Physical Activity in Adolescents: A Validation Using Doubly Labeled Water

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Background: Accurate assessment of physical activity energy expenditure (PAEE) among adolescents is important for surveillance, evaluating interventions, and understanding the relation between energy balance and normal physiological and behavioral growth and development. The purpose of this study was to examine the validity of the Short Questionnaire to Assess Health-Enhancing Physical Activity (SQUASH)13 for measuring PAEE among adolescents. Methods: The participants were seventeen adolescents (9 females; Mean age = 17.53; SD = 0.62). Energy expenditure was measured during a 9-day period with doubly labeled water (DLW). The SQUASH was self-administered on the morning of the 10th day and assessed commuting activities, leisure time activities, household activities, and activities at work and school over the previous 9 days. Results: A Bland-Altman plot indicated that the SQUASH underestimated PAEE compared with DLW by a mean difference of 126 kcal·d⁻¹ (95% limits of agreement: -1,207 to 1,459 kcal·d⁻¹), representative of a 10% underestimation. The Spearman rank order correlation coefficient showed there was a significant association between the SQUASH and DLW (r = .50, P = .04), for estimating PAEE. Conclusion: When using a sample of highly active adolescents, the SQUASH is a valid self-report tool for measuring PAEE at the group and individual rank order level.

Keywords: physical activity energy expenditure, self-report, measurement

Promoting physical activity among youth is important given compelling evidence that engaging in greater amounts of physical activity is associated with greater health outcomes.1,2 Accurate assessment of physical activity is important for surveillance, evaluating interventions, and understanding the relation between energy balance and normal physiological, psychological, and behavioral growth and development.3–5 Despite technological advancements and the development of objective measurement tools to assess physical activity and estimate energy expenditure (EE; eg, accelerometers, heart rate monitors, and combined sensing devices), self-report remains the most feasible and used means of collecting population level activity data.6 Validation of questionnaires assessing physical activity energy expenditure (PAEE) is a challenge, given there is no single accepted validation criterion. The doubly labeled water (DLW) method is considered the gold standard for assessing free-living total energy expenditure (TEE). It is also considered the gold standard for assessing PAEE when combined with measures of resting metabolic rate.3,7 Hence, DLW is useful as a validation criterion.

To date, only a few questionnaires for estimating physical activity related EE in adolescents have been validated using DLW.6,8,9 These include a physical activity questionnaire for adolescents (PAQA) adapted from the International Physical Activity Questionnaire,8 the Minnesota Leisure Time Physical Activity Questionnaire (MLTPAQ),9 the Youth Physical Activity Questionnaire (YPAQ), and the Swedish Adolescent Physical Activity Questionnaire (SWAPAQ).6 Using these questionnaires, underestimations of reported PAEE ranged from 16% to 78% compared with measured values. Underestimations have been attributed to the recall of only leisure time activity and varying degrees of unreported time, in addition to the inappropriate use of adult compendia used to convert adolescents’ self-report activity data into EE.6 There has been little research conducted to quantify the EE of youth10; however, assigning adult values to the energy costs of adolescents can be problematic and may result in substantial error. Specifically, research has shown that youth typically have higher resting metabolic rates than adults, resulting in a larger gross energy cost.11 Since the time Arvidsson et al,8 Corder et al,4 and Slinde et al8 completed their work, a compendium of energy costs for physical activity has been developed, specifically for children and adolescents.10

The Short Questionnaire to Assess Health-Enhancing Physical Activity (SQUASH)12 is a tool used by Dutch government agencies to monitor the physical activity behavior of the adult population and compliance to physical activity guidelines. The SQUASH has the potential to address measurement issues using self-report data in youth and exhibits a number of design properties that could prove advantageous when assessing daily activity in adolescent populations. First, the relatively short duration (approximately 3 to 5 min) required to complete the SQUASH reduces participant burden and may increase adherence among adolescents. Second, the SQUASH assesses domain specific activities including school, work, and during household chores. By prompting activities that may be difficult for adolescents to recall as they occur more spontaneously and without pattern from a day-to-day basis (eg, computer time, time spent doing work at school), the SQUASH aims to reduce the degree of unreported time associated with measures targeting leisure time activity alone.4 Inclusion of items that assess activities of daily

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living in other questionnaires has improved underestimations of PAEE in adolescents.\textsuperscript{9} Lastly, to account for individual differences in activity choice, the SQUASH provides the opportunity for individuals to list the regular type(s) of physical activity they engage in during their leisure-time. In short, the SQUASH enables a more complete assessment of habitual activity levels in youth compared with existing instruments.\textsuperscript{6,8,9}

Although not originally intended as a measure of PAEE, the design and structure of the SQUASH allows for PAEE estimations. Used in conjunction with the compendium of energy costs for physical activity developed for children and adolescents,\textsuperscript{10} improvements to the estimation of PAEE from recall data in adolescents may be achieved. Therefore, the aim of the current study was to examine the measurement of agreement of the SQUASH against DLW for estimating PAEE in an adolescent sample.

**Methods**

**Participants**

The sample included 18 students (10 females) enrolled in an exercise science course at 2 secondary and 1 postsecondary institution in London, Ontario, Canada. The principal investigator made contact with interested students through a designated teacher at each institution. Participants were required to be between the ages of 15 and 18 years, communicate in English, and have no contraindications to being physically active. Informed consent was obtained for participants aged 18 years. Participants under the age of 18 years provided written assent, in addition to, evidence of informed consent from a parent and/or guardian. The study was approved by the manager of research and assessment services of the participating school board, in addition to, the host university’s research ethics board (#15002E). All study measures and the dosage of DLW took place at the Exercise and Health Psychology Laboratory at the host university.

**Anthropometry and Body Composition**

For each measure, participants wore lightweight apparel and removed their shoes. Height and weight were measured in duplicate using a Health-O-Meter Professional height and weight scale (Health-O-Meter 500KL, Boca Raton, FL), according to standard procedures,\textsuperscript{13} and were recorded to the nearest 0.5 cm and 0.1 kg, respectively. Percent body fat and percent lean fat-free mass was measured by dual energy x-ray absorptiometry (iDEXA) using Lunar Prodigy Advance software (GE Healthcare, enCORE 2007 software version 11.40.004, Waukesha, WI). Individuals removed any metal before being scanned while lying supine. The iDEXA was calibrated following the procedures provided by the manufacturer each day before testing.

**Resting Energy Expenditure (REE)**

For practical reasons (time and costs), basal metabolic rate (= REE) was predicted using a standardized set of equations developed by Molnar et al\textsuperscript{14} and previously implemented by Ekelund and colleagues.\textsuperscript{15} The Molnar et al\textsuperscript{14} equations have been validated by indirect calorimetry in an adolescent population and shown to underestimate REE values by an average of 3% [males: 50.9 BW(kg) + 25.3 Ht(cm) – 50.3 A(y) + 26.9; females: 51.2 BW(kg) + 24.5 Ht(cm) – 207.5 A(y) + 1629.8; where BW is body weight, Htt is body height and A is age].\textsuperscript{16} Each REE value was converted from kilojoules and expressed as kilocalories by dividing each value by 4.186.

**DLW**

TEE from DLW was measured over a 9-day period, as described by Westerterp and colleagues.\textsuperscript{17} Following dinner on day 0, a baseline urine sample was collected to determine background levels of isotope enrichment. Participants then ingested an accurately weighed drink of deuterium and oxygen-18 enriched water, corresponding to 0.05 g of deuterium oxide ($\text{D}_2\text{O}$) and 1.10 g of oxygen-18-water ($\text{H}_2\text{O}$) per kilogram of body weight. Immediately after ingestion the dose container was rinsed twice with tap water and this also was ingested. Participants provided a postdose urine sample 4 hours following DLW ingestion and were asked to refrain from food and drink until the following morning. Participants provided additional urine samples and recorded exact collection time from the second and last void of the day on Days 1, 5, and 9. Samples were analyzed in duplicate by continuous-flow isotope ratio mass spectrometry using a Europa Scientific ANCA-GSL GEO 20 to 20 IRMS (Iso-Analytical Limited, Crewe, Cheshire, U.K.) and measurements were standardized against standard mean ocean water. TEE from DLW (TEEDLW) was calculated by the multipoint method using linear regression from the difference between elimination constants of $^2\text{H}$ and $^{18}\text{O}$, based on Schoeller’s estimation of carbon dioxide production,\textsuperscript{18} which normalizes $^2\text{H}^{18}\text{O}$ space ratios to 1.04/1.01 = 1.03.\textsuperscript{19,20} TEE was derived from carbon dioxide production, assuming carbohydrate, fat, and protein substrate oxidation with a food quotient of 0.85.\textsuperscript{20} PAEE was calculated as $\text{PAEE} = 0.9 \times \text{TEE} – \text{REE}$, taking into account a 10% thermic effect of feeding\textsuperscript{3} (PAEEDLW).

**SQUASH**

The questionnaire was self-administered and completed on the morning of Day 10. The questionnaire provides 4 main domains outlining types of activity: (a) commuting activities, (b) leisure time activities, (c) household activities, and (d) activities at work and school. Participants indicated the amount of time they spent in each of the domain-specific activities using 3 main queries: days per last 9 days, average time per day (in minutes), and intensity (light, moderate, intense), except for parts (c) and (d), where intensity is simplified to 2 categories (light or intense).

**Calculating PAEE From the SQUASH**

Total time in physical activity was calculated for each item by multiplying frequency (days per last 9 days) by duration (hours per day). PAEE was calculated as $\text{PAEE} = \text{MET} \times \text{kg body weight} \times \text{time (h)}$. A mean PAEE value was calculated separately for each item. For the commuting and leisure time activities, MET values are assigned for each activity according to intensity: 3.0 MET (light), 5.2 MET (moderate), and 6.5 MET (intense).\textsuperscript{12} An exception was made for the individual sports listed in the leisure time category, in which a MET value was assigned using the compendium of physical activities for children and adolescents.\textsuperscript{18} The light and intense household activities and activities at school and work were assigned a mean MET of 2.25 and 3.75, respectively. Theses averages are representative of MET ranges (1.5 to <3.0 and 3.0 to <4.5) assigned to these types of activity in the youth compendium (eg, computer work, drama class, dusting, raking leaves).\textsuperscript{10} To compute total daily PAEE (PAEE\textsubscript{SQUASH}) for comparison with PAEE\textsubscript{DLW}, individual PAEE scores were summed and divided by the total number of physical activity days recalled (9).
Statistical Analyses

Descriptive statistics were calculated for all variables. The Shapiro-Wilk test of normality was conducted for all physical activity variables before data analyses. In addition, a box-and-whisker plot was created for the PAEE\textsubscript{SQUASH} values to examine if there were any potential outliers.

Limits of agreement between PAEE\textsubscript{DLW} and PAEE\textsubscript{SQUASH} were determined according to recommendations by Bland and Altman\textsuperscript{21} in which the difference between individual DLW- and SQUASH-PAEE (PAEE\textsubscript{DLW} – PAEE\textsubscript{SQUASH}) were plotted against mean PAEE [(PAEE\textsubscript{DLW} + PAEE\textsubscript{SQUASH})/2] (see Figure 1). In addition, the mean difference (bias) between the methods and the 95% limits of agreement (mean ± 2 SD) were calculated. A Spearman correlation coefficient was calculated to assess the degree of association between PAEE\textsubscript{SQUASH} and PAEE\textsubscript{DLW}. All statistical procedures were performed using PASW Statistics 18 (SPSS Inc., Chicago, IL) and GraphPad Prism 5.0 (GraphPad Software Inc., San Diego, CA) software programs.

Results

Data from seventeen (9 females) participants were included in the final analyses. In line with the protocol of the SQUASH, data from 1 female were excluded from analyses as the total minutes of activity per day exceeded 960.\textsuperscript{12} Descriptive data are presented in Table 1.

The Shapiro-Wilk test of normality showed that for the most part, variables concerning physical activity were not normally distributed. Therefore all data are presented as both median (range) and mean (standard deviation). The median (range) and mean (standard deviation) PAEE (kcal·d\textsuperscript{-1}) as measured by DLW was 1281 (163 to 2,107) and 1,219 (517) kcal·d\textsuperscript{-1}, respectively, and the median (range) and mean (standard deviation) PAEE (kcal·d\textsuperscript{-1}) as measured by the SQUASH was 973 (81 to 3,297) and 1,093 (803) kcal·d\textsuperscript{-1}, respectively. With respect to SQUASH data, participants spent the most time being active during their leisure time or when at school and/or work (Table 2).

This is the first study to demonstrate that the SQUASH physical activity questionnaire demonstrates validity as a tool for assessing PAEE among adolescents. Beyond this generalized conclusion, several issues warrant discussion. For measuring PAEE at the group level, the SQUASH agreed well with DLW estimates, with only 10% underestimation. Even after removing the outlier from the dataset, in contrast to DLW, the SQUASH underestimated PAEE by only 19%. This underestimation keeps in line with previously validated physical activity questionnaires such as the YAPQ and SWAPAQ.\textsuperscript{6} Similar to Corder and colleagues,\textsuperscript{6} we used PAEE as our outcome measure, in contrast to Arvidsson et al,\textsuperscript{8} and Slinte et al,\textsuperscript{9} where TEE was calculated. Although TEE has been more frequently used for validating physical activity questionnaires, this is problematic because it incorporates an estimate of REE. Because REE constitutes a significant proportion of TEE, inaccuracies in unreported time can introduce error into the estimation.\textsuperscript{22} For this reason, other outputs such as PAEE are preferable for use as comparators and likely produce more robust results.\textsuperscript{22}

As indicated by the mean time spent in activity (Table 2), PAEE accounted for 22% of TEE for the current sample. While this keeps in line with the component breakdown of TEE (ie, PAEE accounts for 15% to 30% of TEE),\textsuperscript{3} it is surprising that PAEE did not constitute a larger proportion of daily TEE in adolescents who on average participated in exercise and fitness activities of more than 1 hour per day. Despite being designed as a physical activity tool for adults,

![Figure 1 — Differences between physical activity energy expenditure (PAEE) from (PAEE\textsubscript{DLW}) and the lower Short Questionnaire to Assess Health-Enhancing Physical Activity (SQUASH,PAEE) value plotted against average of PAEE\textsubscript{DLW} and PAEE\textsubscript{SQUASH} (n = 17). Solid line indicates mean and dotted lines indicate 95% limits of agreement.](image)

Table 1. Participant Characteristics (N = 17)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>17.50 (0.60)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.00 (8.00)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.00 (13.10)</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>21.30 (5.70)</td>
</tr>
<tr>
<td>REE (kcal·d\textsuperscript{-1})</td>
<td>1,475.10 (339.40)</td>
</tr>
</tbody>
</table>

Abbreviation: REE, resting energy expenditure.
the SQUASH seemed very fitting for the current sample. Unlike existing adolescent questionnaires the SQUASH includes the recall of household physical activities and furthermore distinguishes light from intense household work. Household activities can represent a considerable portion of the day, thus contributing substantially to an individual’s EE. In the current study (see Table 2), our participants spent an average of 36 minutes per day engaged in household activity and another 21 minutes per day performing odd jobs. Had the SQUASH not captured these activities, it is likely that greater underestimations of PAEE would be found. On the contrary, not a single participant reported spending any time doing gardening activity during ones leisure time. Slight modifications to the SQUASH (ie, replace the gardening item with a leisure time activity that is more characteristic of an adolescent’s activity behavior like active video gaming) may target more of their total activity time and improve the overall validity of the SQUASH.

Despite the improved mean estimation found in the current study, it should be noted that the large variability indicates that while the SQUASH demonstrates validity for estimating PAEE at the group level, noticeable individual differences exist. With respect to the rank order of individuals by PAEE, the Spearman correlation between the PAEE_SQUASH and PAEE_DLW found in the current study (ie, \( r = .50 \)) is in line with those of previous studies. Corder et al reported correlation coefficients of \( r = .46 \) and \( r = .40 \) between PAEE DLW and the YPAQ and SWAPAQ, respectively, while Slinte et al and Arvidsson et al reported correlation coefficients of \( r = .49 \) and 0.62 between TEE DLW and the MLTPAQ and PAQA, respectively. The current study revealed a large effect size, providing support for the SQUASH as a valid instrument for ranking participants according to PAEE.

An important consideration in this study was the use of the children and youth compendium to assign energy costs to physical activities. Although this compendium has been critiqued, as only 35% of the MET values in the compendium are based on data measured in youth and the majority of MET values still based on adult-derived data, youth-derived measures are available for the most of the SQUASH items and the individualized leisure-time activities (eg, walking, biking, and common sports) listed by the current sample. The current work provides some support that the child and youth compendium can be used to estimate PAEE from self-report, as opposed to using adult-derived values and adjusting for the higher REE of adolescents; however, further updates to the compendium are required to increase in the overall number of MET values that are derived specifically from children and adolescent samples.

**Strengths and Limitations**

Modified from its original application, the SQUASH has demonstrated to be a good tool for estimating PAEE in adolescents. The SQUASH assesses activity in multiple domains (commuting, leisure time, household, and work and school), which improves upon other measures that tend to assess activities in a limited number of domains. The inclusion of household activities in the SQUASH may be the greatest improvement over other measures, as it can distinguish between light and intense household work. Design features unique to the SQUASH may also have resulted in its improved performance. For example, the SQUASH uses open-ended questions to assess leisure time physical activities, enabling researchers to obtain a comprehensive report of each participant’s physical activity behavior. In addition, it requires that participants specify the intensity (light/moderate/intense) with which they engaged in each activity listed. This approach allows for a more individualized approach than other questionnaires, such as the YPAQ, which merely assign an average intensity level to a fixed list of leisure activities (eg, classifying tennis as a moderate-intensity activity among all participants). Furthermore, to improve the accuracy of self-report physical activity estimates, researchers are charged with selecting the shortest recall period possible while still being able to capture usual physical activity behaviors. The SQUASH was modified so participants recalled physical activity over a 9-day period. Evidence exists that recall error increases with the duration of recall time. This may help explain why the SQUASH improved estimates of physical activity related EE in contrast to the MLTPAQ, which assesses physical activity over the course of the previous year.

Despite its strengths, this study is not without limitations. The small sample size is a limitation to the current work. This shortcoming was unavoidable due to the high cost associated with the DLW method. Furthermore, as previously mentioned self-report physical activity data are found to be more accurate when the recall period is shorter. The DLW method provides PAEE measures over...
a relatively long time period (9 days). The time frame for physical activity recall by the SQUASH items was modified to correspond with the DLW method. Increasing the recall period beyond the traditional 1-week period may have led to some inaccuracies in the self-report activity data.

Implications

The present findings are significant for a number of reasons. Despite increased access to objective physical activity measures such as accelerometers, self-report remains the most time and cost-efficient, convenient, and universally accessible means for assessing physical activity. According to the World Health Organization’s Global Strategy on Diet, Physical Activity and Obesity, childhood obesity and physical inactivity is on the rise around the world and is among the most serious public health challenges of the 21st century.25 Intervention efforts designed to help children achieve a healthy energy balance have been underway for some time and the availability of valid self-report instruments capable of measuring EE could play an important role in the evaluation of such initiatives. DLW represents the gold standard for measuring EE and only a handful of physical activity questionnaires have been validated against DLW. Thus, this study provides the best possible evidence that the SQUASH can serve as a valid measure of PAEE in adolescents when interpreted against the Ridley et al.10 compendium. Finally, the SQUASH is a short and simple questionnaire, and as such it would be amenable to measuring the PAEE of large adolescent populations.

In conclusion, the high level of agreement between PAEE_{SQUASH} and PAEE_{DLW} indicates that the SQUASH demonstrates good validity as a tool for rank ordering participants according to PAEE and for estimating actual PAEE at the group level. Nevertheless, the current sample consisted of a highly active, athletic group of adolescents. Before the SQUASH can be recommended as a valid questionnaire for assessing PAEE and health related outcomes among adolescents, these findings need to be replicated in larger and more diverse adolescent samples.

Acknowledgments

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References