Relationship between activity levels, aerobic fitness, and body fat in 8- to 10-yr-old children

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Rowlands, Ann V., Roger G. Eston, and David K. Ingleedew. Relationship between activity levels, aerobic fitness, and body fat in 8–10-yr-old children. J. Appl. Physiol. 86(4): 1428–1435, 1999.—The relationships between children’s activity, aerobic fitness, and fatness are unclear. Indirect estimates of activity, e.g., heart rate (HR) and recall, may mask any associations. The purpose of this study was to assess these relationships by using the Tritrac-R3D, a pedometer, and heart rate. Thirty-four children, ages 8–10 yr, participated in the study. The Tritrac and pedometer were worn for up to 6 days. HR was measured for 1 day. Activity measured by Tritrac or pedometer correlated positively to fitness in the whole group (Tritrac, \( r = 0.66 \); pedometer, \( r = 0.59; P < 0.01 \)) and in boys and girls separately (\( P < 0.05 \)) and correlated negatively to fatness in the whole group (\( r = -0.42, P < 0.05 \)). In contrast, HR did not correlate significantly to fitness, and HR of \( > 139 \) beats/min correlated positively to fatness in girls (\( r = 0.64, P < 0.05 \)). This suggests that HR is misleading as a measure of activity. This study supports a positive relationship between activity and fitness and suggests a negative relationship between fatness and activity.

physical activity; accelerometry; pedometry; heart rate

whether a relationship truly exists between the activity levels of children, their aerobic fitness, and their levels of fatness is controversial. This is partly due to the variety of self-report methods (e.g., questionnaire, diary) and objective methods [heart rate (HR), movement counters] used in studies to quantify physical activity (27). Comparability between such studies is also limited, depending on whether behavioral activity measures or energy expenditure measures are used. If energy expenditure is reported, it should be adjusted for body size, because the cost of moving the body increases with body size (32). Problems with adjusting energy expenditure to account for differences in body size can lead to spurious results; hence, the appropriate scaling method has to be selected and interpreted with caution (19). Bar-Or and Baranowski (6) recommended that, when the relationship to adiposity is being determined, physical activity measures should be expressed as body movement and not as energy expended.

A positive relationship between physical activity and aerobic fitness is established in adults (2, 7, 37). However, the relationship is less clear in children. The results of 20 studies that focus on the relationship between physical activity and aerobic fitness in adolescents were presented in a review by Morrow and Freedson (26). Fifty-three correlation coefficients were produced, the median of which was 0.17. Of the 37 conclusions identified by the authors, 17 suggested a positive relationship, and 20 suggested no relationship. It should be noted that all studies with a sample size of 186 or larger detected a significant relationship between activity and fitness. The authors concluded that there was a small to moderate relationship between physical activity and aerobic fitness in children, youth, and adolescents. They suggested that the weak association identified may be due to one of three things: poor measurement of physical activity, the high level of aerobic fitness in children and adolescents, or the lack of a relationship in the first place.

For a detailed discussion of studies that compare activity levels in obese and normal children, see reviews by Bar-Or and Baranowski (6) and Ward and Evans (32). The former review concluded that obese children tended to be less physically active than their nonobese counterparts. The latter review found similar numbers of studies for and against an inverse relationship between fat and physical activity levels in children. When total energy expenditure (normalized for fat free mass) is measured, as opposed to the behavioral aspect of physical activity, there appears to be no difference between obese and nonobese children (19). This highlights the importance of differentiating between physical activity and energy expenditure. It is unclear which aspects of physical activity are important in regulating body weight. Hence it is important to measure as many of these factors as possible. Goran (19) has suggested intensity, activity time, metabolic efficiency, overall energy cost, and the type of physical activity as important factors for consideration.

It appears that, in this area of research, findings are somewhat dependent on the method used to measure physical activity. Observation studies appear to detect a relationship between activity, fitness, and fatness (11, 31), but, when activity monitors or questionnaires are...
used, the results vary (1, 21). Observation techniques are capable of detecting many aspects of physical activity. Possibly, more than one of these aspects of physical activity or the interactions of several are instrumental in weight control.

The Tritrac triaxial accelerometer is capable of recording intensity, frequency, and duration aspects of activity. Both the Tritrac and the Yamax Digiwalker DW-200 pedometer have been shown to be valid tools for the measurement of energy expenditure in a variety of physical activities in 8- to 10-yr-old children (17). Eston et al. (17) observed that, for all activities, the Tritrac was a significantly better predictor of energy expenditure than was HR and that, for children's play activities, both the Tritrac and Yamax pedometer were significantly better predictors of energy expenditure than was HR. These instruments should, therefore, provide valid activity data to assess whether any differences exist in activity levels of children with different fatness levels and fitness levels. They would also provide an objective output which would be directly comparable across studies.

The purpose of this study was to assess the relationship between habitual daily activity and levels of body fatness and aerobic fitness in 8- to 10-yr-old children. Activity was measured by three methods: the Tritrac-R3D accelerometer, the Yamax Digiwalker DW-200 pedometer, and the Sport Tester PE4000 HR monitor. This allowed the identification of the activity measures that capture the aspects of activity most pertinent to fitness and fatness.

METHODS

Subjects

Subjects were 34 children (17 boys and 17 girls), ages 8.3–10.8 yr [9.5 ± 0.7 (SD) yr; mass, 31.2 ± 5.0 kg; height 134.4 ± 7.1 cm] from two local primary schools in the Bangor, North Wales, area. Written informed consent was obtained from the children's parents or guardians.

Anthropometric Assessment

Anthropometric data were recorded in each child's own home. Height was measured by using a free-standing Seca stadiometer, and mass was measured by using Tanita TBF-305 body composition scales (Tanita UK, Middlesex, UK). Skinfold measurements were taken at seven sites: triceps (vertical fold midway between the olecranon process and the acromion process), biceps (vertical fold at the same level as the triceps skinfold), abdominal (vertical fold 2 cm lateral to the umbilicus), subscapular (oblique skinfold 1 cm below the inferior angle of the scapula), suprailium (diagonal fold immediately above the crest of the ilium on a vertical line from the anterior axillary fold), thigh (vertical fold midway between the inguinal crease and the proximal border of the patella), and medial calf (vertical fold at maximal calf circumference). Each skinfold was measured twice with Holtain skinfold calipers (Crosswell, Crymych, South Wales, UK). If the readings differed by >1 mm, a third reading was taken and the mean was recorded. The seven skinfolds were summed, and the total was used as a measure of total body fat.

Assessment of Daily Physical Activity

Physical activity was measured by three methods: triaxial accelerometry (Tritrac-R3D, models T303 and T303A; Professional Products, Reining International, Madison, WI), pedometry (Yamax Digiwalker DW-200, Yamasa, Tokyo, Japan), and HR telemetry (Sport Tester PE4000, Polar Electro, Kemupele, Finland). The Tritrac and the pedometer were stored in a money belt which the child wore around the waist. Stitched pockets ensured the monitors were held tightly and did not move around inside the money belt. The Tritrac is initialized and downloaded via a computer interface and has no external controls that can be manipulated. However, the pedometer has a reset button. To prevent any tampering, a small padlock on the money belt prevented access to the inside of the pockets. The child's parents kept the key. The pack was worn by the subjects from when they got up in the morning until they went to bed at night, except for bathing and showering, for up to 4 weekdays and 2 weekend days. The mean number of days the pack was worn was 4.93 (range, 3–6 days). Every morning, the parents reset the pedometer to zero; every evening, when the child went to bed, they recorded the number of counts on the pedometer. The Tritrac was programmed to record minute-by-minute activity counts. Minute-by-minute HR was measured for 1 weekday, from 8 AM until bedtime. An investigator (A. V. Rowlands) visited the child's house before school and attached the transmitter to the child's chest via a belt. The receiver was stored in the locked money belt.

The children reported no problems with wearing the pack containing the Tritrac and the pedometer. However, in a pilot study, children reported the HR belt to be uncomfortable. Consequently, in the main study, the children were asked to wear the HR monitor for only 1 day. Even then, some of the children removed it before the day was up, leading to a somewhat lower number of children with HR data than with Tritrac and pedometer data.

Output Measures of Physical Activity

Tritrac-R3D activity monitor. The software package for the Tritrac provides activity counts for each of the three dimensions as well as the vector magnitude. Only the vector magnitude was used in this study, because previous research has shown it to be superior compared with any one vector when used to assess a variety of activities (17). Each output represents an average of 1 min of activity, not just the level of activity at the instant the reading is taken. This is important, because many children's activities do not last an entire minute. Numbers of counts per minute were assigned intensity levels (Table 1) on the basis of the results of our previous study that validated Tritrac counts against the criterion of scaled oxygen uptake (VO₂) for a variety of intensities of activities, ranging from sitting and crayoning to hopscotch

<table>
<thead>
<tr>
<th>Exercise Classification</th>
<th>Tritrac, counts/min</th>
<th>Approximate MET Value</th>
<th>Equivalent Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light</td>
<td>&lt;300</td>
<td>&lt;3.5</td>
<td>Crayoning</td>
</tr>
<tr>
<td>Light</td>
<td>300–1,000</td>
<td>3.5–4.5</td>
<td>Playing catch</td>
</tr>
<tr>
<td>Moderate</td>
<td>1,000–2,000</td>
<td>4.5–6.0</td>
<td>Walking at 4 km/h</td>
</tr>
<tr>
<td>Vigorous</td>
<td>2,000–3,500</td>
<td>6.0–8.0</td>
<td>Walking at 6 km/h</td>
</tr>
<tr>
<td>Hard</td>
<td>3,500–4,500</td>
<td>8.0–9.5</td>
<td>Running at 8 km/h or</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>playing hopscotch</td>
</tr>
<tr>
<td>Very hard</td>
<td>&gt;4,500</td>
<td>&gt;9.5</td>
<td>Running at 10 km/h</td>
</tr>
</tbody>
</table>

*MET, metabolic equivalent (1 MET = 3.5 ml·kg⁻¹·min⁻¹).
and running at 10 km/h (17). This allowed time spent at each intensity to be calculated, as well as total daily activity counts (ΣTritrac). Minutes spent in moderate activity and above (=modTritrac) and minutes spent in vigorous activity and above (=vigTritrac) were recorded.

HR monitor. Each recorded HR represents the average of a few successive beats at the time the reading is taken, and, therefore, is not representative of all HRS during the entire minute. Three output measurements were taken from the HR data: the number of minutes spent with the HR >139 beats/min (HR >139 beats/min); the number of minutes spent with the HR >159 beats/min (HR >159 beats/min); and the average net HR (HR minus baseline HR divided by the number of data points). The former two measurements are frequently reported and thus allow comparison with previous data. Welsman and Armstrong (35) report these intensities to be equivalent to walking on the treadmill at 6 km/h and jogging at 8 km/h, respectively, in children ages 11–16 yr. These are equivalent to our “vigorous” and “hard” categories for the Tritrac output. The net HR measure accounts for individual differences in resting HR and provides an index of the Tritrac output. The net HR measure accounts for individual differences in resting HR and provides an index of activity. Baseline HR was calculated by averaging the five lowest HRs attained during the day’s monitoring (28). The Tritrac and the HR monitor were set to the same watch to ensure that they could be matched temporarily.

Pedometer. The pedometer does not measure intensity or time. The output measure was simply accumulated counts for each day (ped cts).

Measurement of Aerobic Fitness

Endurance time (in minutes and seconds) on the Bruce maximal treadmill test was used to measure aerobic fitness. The protocol was as described elsewhere (9). The treadmill was programmed to increase in speed and grade every 3 min. Speed and gradient (respectively) for stages 1–7 were 1.7 miles/h, 10%; 2.5 miles/h, 12%; 3.4 miles/h, 14%; 4.2 miles/h, 16%; 5.0 miles/h, 18%; 5.5 miles/h, 20%; and 6.0 miles/h, 22%. In this test all children, regardless of fitness level or size, undergo the same protocol. HR was recorded throughout. The test ended when maximal volitional effort was attained. The HR monitor was also recorded to confirm a maximal effort. The results of one boy’s fitness test were rejected because he did not appear to have reached a maximal level. This was confirmed by a relatively low final HR of 186 beats/min.

RESULTS

The descriptive data (means ± SD), characterized by gender, are presented in Table 2. Mean height and mass of the boys and girls are within the 25th–75th percentile norms for British children of the same age (30). Each activity measure represents an average of the days measured, except for HR, which was recorded on only 1 day. Typical graphs of 1 day’s activity, as recorded by the Tritrac and HR for the same subject, are shown in Fig. 1.

Of the 34 subjects, 3 subjects each lost 2 days of activity data because they forgot to wear the pack. The number of days the pack was worn also varied because of prearranged missed days due to weddings, parties, and some sporting activities, e.g., rugby matches. The present size of the Tritrac makes it impractical to wear on such occasions. The pedometer alone would not have caused a problem.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height, cm</td>
<td>174 ± 5.6</td>
<td>174 ± 5.6</td>
</tr>
<tr>
<td>Mass, kg</td>
<td>75 ± 10.2</td>
<td>75 ± 10.2</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>23 ± 2.1</td>
<td>23 ± 2.1</td>
</tr>
<tr>
<td>$\Sigma$ 2 skinfolds, mm</td>
<td>17.0 ± 6.5</td>
<td>17.0 ± 6.5</td>
</tr>
<tr>
<td>$\Sigma$ 7 skinfolds, mm</td>
<td>61.4 ± 27.6</td>
<td>61.4 ± 27.6</td>
</tr>
<tr>
<td>Endurance time, min</td>
<td>12.7 ± 2.1</td>
<td>12.7 ± 2.1</td>
</tr>
<tr>
<td>Maximum HR in fitness test, beats/min</td>
<td>159</td>
<td>159</td>
</tr>
<tr>
<td>HR &gt;139 beats/min (modTritrac)</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>HR &gt;139 beats/min (vigTritrac)</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Pedometer counts</td>
<td>16,035</td>
<td>16,035</td>
</tr>
<tr>
<td>$\Sigma$ Tritrac</td>
<td>369,057</td>
<td>369,057</td>
</tr>
<tr>
<td>Endurance test</td>
<td>32.3</td>
<td>32.3</td>
</tr>
<tr>
<td>Mean net HR, beats/min</td>
<td>16.2</td>
<td>16.2</td>
</tr>
</tbody>
</table>

Table 2. Descriptive data

The correlation between the minute-by-minute Tritrac data and the minute-by-minute HR data was computed for each subject. These intrindividual correlations were converted to z scores, averaged, and then converted back to give a group mean correlation. The range of the individual correlations for boys was 0.29–0.84, group mean was 0.63; the range of individual correlations for girls was 0.38–0.73, group mean was 0.60. The ΣTritrac and ped cts for the entire time the instruments were worn were computed for each subject. The correlation between ΣTritrac and ped cts was 0.85 for boys (P < 0.001, n = 15) and was 0.88 for girls (P < 0.001, n = 14).

Tests for normal distribution revealed that the skinfold and HR data (HR >139 beats/min, HR >159 beats/min, and mean net HR) were skewed. Log transformation of these variables, as recommended by Tabachnick and Fidell (29), resulted in normal distributions. These log-transformed variables were used in all analyses. (We also ran the analyses by using the original untransformed variables, and the results were not notably different.)

The upper part of Table 3 shows the correlations between Tritrac and pedometer measurements of activ-
ity, fitness, and fatness for all days combined. All output measures from the Tritrac and the pedometer were significantly positively correlated with aerobic fitness for the whole group \((P < 0.01)\) and for girls alone \((P < 0.05)\), although not for boys alone. The output measures from the Tritrac and the pedometer were significantly negatively correlated with fatness \((P < 0.05)\) for the whole group but not for boys alone or for girls alone. Correlations of these output measurements with fitness were not significantly different for boys and girls, nor were the correlations of the output measurements with fatness. Examination of the scatterplots supported the similarity of these relationships for boys and girls.

The correlations of pedometer counts with fatness and with fitness were compared with those of \(\Sigma\)Tritrac with fatness or fitness by using a method described by Meng et al. (25). These correlations were not significantly different.

The lower part of Table 3 shows the correlations of Tritrac, pedometer, and HR with fitness and fatness for the 1 day on which HR was measured. To allow a fair comparison between Tritrac, pedometry, and HR, only subjects with data for both HR and Tritrac were included. \(\Sigma\)Tritrac and \(>=\)modTritrac were significantly positively correlated \((P < 0.05)\) with fitness for the whole group and for girls alone \((P < 0.05)\). HR \(\geq 139\) beats/min was significantly positively correlated with fatness for girls \((P < 0.05)\). In other words, the fatter the girls, the longer they spent with elevated HRs. However, there was no association between mean net HR and fatness.

**Table 3. Correlations between measures of physical activity and fitness and fatness**

<table>
<thead>
<tr>
<th>Activity Measure/Group</th>
<th>Correlations With Endurance Time (Bruce test)</th>
<th>Correlations With Log 7.5 Skinfolds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(r) (\ P) (n)</td>
<td>(r) (\ P) (n)</td>
</tr>
<tr>
<td>All days combined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Sigma)Tritrac</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.66* 0.000 32</td>
<td>-0.42† 0.015 33</td>
</tr>
<tr>
<td>Boys</td>
<td>0.64* 0.007 16</td>
<td>-0.28 0.279 17</td>
</tr>
<tr>
<td>Girls</td>
<td>0.55† 0.029 16</td>
<td>-0.32 0.231 16</td>
</tr>
<tr>
<td>&gt;=ModTritrac</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.66* 0.000 32</td>
<td>-0.41† 0.017 33</td>
</tr>
<tr>
<td>Boys</td>
<td>0.61† 0.013 16</td>
<td>-0.25 0.344 17</td>
</tr>
<tr>
<td>Girls</td>
<td>0.65* 0.007 16</td>
<td>-0.40 0.121 16</td>
</tr>
<tr>
<td>&gt;=VigTritrac</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.61* 0.000 32</td>
<td>-0.42† 0.016 33</td>
</tr>
<tr>
<td>Boys</td>
<td>0.53† 0.035 16</td>
<td>-0.23 0.381 17</td>
</tr>
<tr>
<td>Girls</td>
<td>0.54† 0.031 16</td>
<td>-0.38 0.141 16</td>
</tr>
<tr>
<td>Pedometer counts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.59* 0.001 27</td>
<td>-0.42† 0.025 28</td>
</tr>
<tr>
<td>Boys</td>
<td>0.50 0.066 14</td>
<td>-0.22 0.429 15</td>
</tr>
<tr>
<td>Girls</td>
<td>0.58 0.037 13</td>
<td>-0.49 0.092 13</td>
</tr>
<tr>
<td>1 day only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Sigma)Tritrac</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.53† 0.016 20</td>
<td>-0.37 0.089 22</td>
</tr>
<tr>
<td>Boys</td>
<td>0.49 0.130 11</td>
<td>-0.39 0.210 12</td>
</tr>
<tr>
<td>Girls</td>
<td>0.67† 0.049 9</td>
<td>-0.24 0.514 10</td>
</tr>
<tr>
<td>&gt;=ModTritrac</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.47† 0.037 20</td>
<td>-0.14 0.536 22</td>
</tr>
<tr>
<td>Boys</td>
<td>0.18 0.603 11</td>
<td>0.15 0.639 12</td>
</tr>
<tr>
<td>Girls</td>
<td>0.78† 0.014 9</td>
<td>-0.25 0.488 10</td>
</tr>
<tr>
<td>&gt;=VigTritrac</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.34 0.139 20</td>
<td>-0.19 0.399 22</td>
</tr>
<tr>
<td>Boys</td>
<td>0.10 0.765 11</td>
<td>-0.03 0.935 12</td>
</tr>
<tr>
<td>Girls</td>
<td>0.44 0.236 9</td>
<td>-0.08 0.830 10</td>
</tr>
<tr>
<td>Pedometer counts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.50 0.056 15</td>
<td>-0.30 0.247 17</td>
</tr>
<tr>
<td>Boys</td>
<td>0.10 0.811 8</td>
<td>-0.00 0.996 9</td>
</tr>
<tr>
<td>Girls</td>
<td>0.63 0.128 7</td>
<td>-0.27 0.526 8</td>
</tr>
<tr>
<td>Log HR (\geq 139) beats/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.08 0.746 20</td>
<td>0.14 0.532 22</td>
</tr>
<tr>
<td>Boys</td>
<td>0.08 0.811 11</td>
<td>0.09 0.783 12</td>
</tr>
<tr>
<td>Girls</td>
<td>-0.24 0.530 9</td>
<td>0.64 0.048 10</td>
</tr>
<tr>
<td>Log HR (\geq 159) beats/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.01 0.955 20</td>
<td>0.12 0.588 22</td>
</tr>
<tr>
<td>Boys</td>
<td>-0.08 0.817 11</td>
<td>0.16 0.630 12</td>
</tr>
<tr>
<td>Girls</td>
<td>-0.46 0.217 9</td>
<td>0.61 0.059 10</td>
</tr>
<tr>
<td>Log mean net HR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>0.29 0.215 20</td>
<td>-0.11 0.612 22</td>
</tr>
<tr>
<td>Boys</td>
<td>0.16 0.643 11</td>
<td>0.16 0.611 12</td>
</tr>
<tr>
<td>Girls</td>
<td>0.16 0.675 9</td>
<td>-0.16 0.654 10</td>
</tr>
</tbody>
</table>

Significant correlations, *\(P < 0.01\); †\(P < 0.05\).
Considering the above, it would appear that Tritrac outputs and peds all added significantly to fatness in predicting fitness. Further analyses were conducted for the day on which HR was measured and, as previously, only subjects with data for both HR and Tritrac were included. Only \( \geq \text{mod Tritrac} \) and peds added significantly to fatness in predicting fitness.

A two-way mixed analysis of variance compared boys' and girls' weekday and weekend activity levels (Fig. 2). This showed that weekend activity levels were significantly lower than weekday activity levels (Fig. 1, \( \text{df} = 5.66, P < 0.05 \)).

**DISCUSSION**

**Main Findings**

The main findings in this study are 1) the significant positive relationship between physical activity levels and fitness and 2) the significant negative relationship between physical activity levels and fatness. Both activity monitors, by utilizing direct measures of movement, identified these relationships. The correlations of peds with fitness and fatness were very similar to, and not significantly different from, those from the Tritrac. This finding supports the validity of the pedomter as a tool for the assessment of children's physical activity. In consideration of the above, the lack of expected relationships between HR, fitness, and fatness throws doubt on the use of HR as an appropriate method for the assessment of children's activity. HR was not significantly correlated with fitness, and, in girls, HR \( > 139 \) beats/min was significantly positively correlated with fatness.

**Normative Comparisons**

The average \( \Sigma \text{Tritrac} \) values of 375,972 and 310,941 for boys and girls, respectively (Table 2), compare well with an earlier study on children of similar age. Welk and Corbin (34) report that 35 boys, ages 9–11 yr, averaged 322,028 counts over 3 days of measurement.

The percentage of time that boys and girls spent above HR thresholds of 139 beats/min (7.2 and 6.0% for boys and girls, respectively) and 159 beats/min (3.3 and 1.7% for boys and girls, respectively) in this study (Table 2) is similar to results from earlier research. Armstrong et al. (4) found that 11- to 16-yr-old boys and girls spent 6.1 and 4.8%, respectively, of their day with their HR exceeding 139 beats/min, and 2.7 and 1.6%, respectively, with their HR exceeding 159 beats/min. The average net HR in this study (32.26 beats/min for boys, 29.32 beats/min for girls) is also similar to that in earlier research. Welk and Corbin (34) found an average net HR of 32.4 beats/min. Janz et al. (22) identified a slightly higher average net HR of 34.3 beats/min in 76 children (ages 6–17 yr) over 3 days of monitoring.

The mean endurance times on the Bruce maximal treadmill test were compared with norms developed by Cumming et al. (12). The mean time for the boys (12.61 min) was very similar to the norms for both 8- to 9- and 10- to 12-yr-old boys (12.6 and 12.7 min, respectively). However, the mean time for the girls (10.19 min) was considerably lower than the norms of 11.8 and 12.3 min for 8- to 9- and 10- to 12-yr-old girls, respectively. The

![Graph showing activity levels in boys (\( \bullet \), \( n = 17 \)) and girls (\( \bullet \), \( n = 17 \)). Values are means ± SE.](http://jap.physiology.org/2017/04/10.1203.3)
mean time for the girls corresponded with a score between the 10th and 25th percentile for 8- to 9-yr-old girls and a score below the 10th percentile for 10- to 12-yr-old girls. This is surprising, because, if anything, one would expect the volunteers to be fitter than average, and there is no evidence that average children's fitness levels have changed in recent years. Armstrong and McManus (3) have directly determined the peak $V_O^2$ of large numbers of children and obtained results similar to those obtained 50 years ago in the United States.

A particular strength of the present study was the measurement of activity for the entire day. The time of day when physical activity is assessed may be crucial in determining the activity levels of children differing in adiposity level. Obese boys have been observed to be substantially less active at home and somewhat less active outside the home when compared with normal-weight siblings. However, when observed in the playground, they were equally active (33).

Relationships of Physical Activity with Aerobic Fitness and Fat Levels

Irrespective of the output selected from the Tritrac, it was significantly correlated with fitness and fatness for the whole group, as were the peds (Table 3). It was important to look at the genders separately. Girls carry higher levels of body fat and are less active than boys (10); this could lead to a spurious relationship between activity and fat for the group as a whole. However, the sizes of the effects were not significantly different when genders were separated. An examination of the scatterplots confirmed the relationship was similar for both genders.

Levels of body fat are very influential on the results of a weight-bearing fitness test, e.g., treadmill tests. Cunningham et al. (13) determined the maximal $V_O^2$ ($V_{O2max}$) of 28 12-yr-old boys on a treadmill. Only fat mass contributed significantly to the variance in fitness; activity levels added little. However, activity levels were only measured over 1 day. In addition, time spent above a HR threshold was used as the activity measure. In our study, HR was shown to be a poor predictor of fitness (Table 4). When activity measures from all days were used, all output measures from the Tritrac and pedometer added significantly to the variance in fitness after taking fatness into account. When only 1 day of activity was considered, the only measurement that added significantly to fatness in accurate prediction of fitness was minutes spent in moderate and greater activity, as assessed by the Tritrac.

Boreham et al. (8) conducted a large study of 1,015 older children (12- and 15-yr-old children) and found physical activity, assessed by questionnaire, to be significantly associated with aerobic fitness, as assessed by the shuttle run, in boys. In girls, sports participation was significantly associated with fitness and fatness. Odds ratios demonstrated that changes in activity levels were most likely to affect fitness levels in boys but fatness levels in girls. Boreham et al. suggested that prolonged vigorous activity was needed for increases in fitness in 12- and 15-yr-old children. Overall, our study does not support this contention for 8- to 10-yr-old children. Summed counts by either the Tritrac or the pedometer correlated with fitness as highly, or more highly, than did measures of moderate or vigorous activity. This suggests that, in this sample of children, total and moderate activity influence fitness levels at least as much as vigorous activity does.

HR Measures of Physical Activity

For girls, the positive correlations of fatness with time spent above the HR thresholds were in the opposite direction to that we expected (Table 3). A positive relationship between time spent above HR thresholds and levels of body fatness has been identified previously. Gilliam (18) found that 7-yr-old obese boys ($n = 5$) spent nearly twice as long as did lean boys ($n = 5$) with their HRs between 120 and 149 beats/min. This was despite spending the same amount of time with HRs $>150$ beats/min. In a sample of 9- to 10-yr-old boys ($n = 11$), Atomi et al. (5) found that time spent above the HR corresponding to the lactate threshold correlated significantly but negatively with the $%V_{O2max}$ at the lactate threshold. However, in contrast, time spent above the lactate threshold had a significant positive correlation with $V_{O2max}$. Both the Atomi et al. study and the present study used only 1 day of HR monitoring. When measuring HR over 3 days, Welsman and Armstrong (35) found no significant correlations between time spent above various HR thresholds and peak $V_O^2$ in 11- to 16-yr-old children (28 boys and 45 girls).

Although $=\text{vigTritrac}$ and HR $>139$ beats/min theoretically measure the same intensity of activity, their relationships with fitness and fatness are quite different (Table 3). This indicates that, in practice, the two measures do not measure the same thing. It is possible that increased levels of body fat increase the cardiovascular stress, and hence HR, of the subject during normal activities. This could cause the HR to be elevated above these thresholds when moderate and vigorous physical activity is not taking place. Taking into account the resting HR (mean net HR) eliminated the positive relationship between fat and HR in girls, although the relationship in boys was unchanged.

Direction of Causation

This study provides support for a positive association between activity levels and aerobic fitness and for a smaller negative association between activity levels and body fat. It does not show, however, whether inactivity causes decreased fitness and increased levels of body fat. It could be that low levels of fitness and/or increased body fat cause children to be inactive. There is evidence to suggest that low activity levels in 3- to 4-yr-old boys precede fatness in 8-yr-old boys (23). However, the activity levels of 12-mo-old infants were related to their fat levels at 6 and 9 mo of age (24).

Possible Causes of Reduced Activity Levels

Dietz (14) has suggested a causal relationship between time spent watching television and obesity: the
more time spent watching television, the higher the risk of obesity. Time spent in inactive pursuits may be just as important as time spent participating in physical activity in determining the risk of obesity. Epstein et al. (16) reported that a decrease in sedentary behaviors is an important factor in the treatment of childhood obesity.

There are an increasing number of purely sedentary leisure pursuits offered to children: television watching, video games, personal computing, even motorized bikes. These sedentary pastimes are pursued at the expense of other, more active, pastimes. Additionally, it has been suggested that increased viewing of television leads to increased snacking (14). The reduced accessibility of unorganized physical activities compounds these problems. In the UK, parents are less willing than in the past to allow unsupervised children out to play or to walk and/or cycle to school because of fears of traffic dangers and abduction (15). It is likely that this physical inactivity will lead to obesity. There is also some evidence (36) to suggest that obese children have less favorable views of endurance-type physical activities than do slim children; this would also tend to perpetuate inactivity.

Implications

This study highlights the contrasting relationships of physical activity with fitness and fatness which are produced when different activity measures are used. Direct measurement of movement, made by using accelerometry and pedometry, reveals different relationships with fitness and fatness compared with inferences concerning physical activity based on HR measurements, particularly when threshold values are used. HR measurements are frequently used to validate activity measures such as accelerometers and questionnaires. This study indicates that this practice is misleading and may actually hamper the identification of more appropriate measurements of activity.

Our results suggest that inactivity in childhood is linked to increased levels of body fat. Inactivity is only one of the factors linked with obesity; however, it is perhaps one of the easiest to modify. The identification of the pedometer as a valid tool for the assessment of physical activity is an important factor in the treatment of childhood obesity. In this sample of 8- to 10-year-olds, low fitness levels and, to a lesser degree, increased fatness were related to decreased-activity levels. Total daily activity was as strongly associated with fitness and fatness as was time spent in moderate and vigorous activities. Time spent above HR thresholds may be exceeded more often in an overweight child than in a similarly active lean child. The pedometer is a good measure of total daily activity and would be an excellent tool for large studies.

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REFERENCES


