Inter-Relationships Among Physical Activity, Body Fat, and Motor Performance in 6- to 8-Year-Old Danish Children

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This study examined the interrelationships among physical activity (PA), percent body fat (%BF), and motor performance (MP) in 498 6- to 8-year-old Danish children. PA was assessed by accelerometer, %BF was calculated from skinfolds, and the Koordinations Test für Kinder along with a throwing accuracy test was used to assess MP. PA was not correlated with %BF, but was significantly correlated with MP. The strongest correlations existed between %BF and MP. Low %BF/High PA had higher MP scores compared with High %BF/Low PA, and within the High %BF groups MP was higher in the High PA versus Low PA group. When comparing PA by %BF and MP groups, boys in the Low %BF/High MP had higher PA than both the Low %BF/Low MP and High %BF/Low MP groups. In girls, PA was highest in the High %BF/High MP group. This study highlights the complex interrelationships among PA, %BF, and MP in children and the need to develop fundamental motor skills during childhood.
Childhood obesity is a critical public health issue in most developed countries (14). Although obesity is now recognized as a complex multifactorial trait (5,12), lack of physical activity is considered one of the leading contributors to its development (17). In the U.S. less than half of 6–11 year old children meet the recommendation for physical activity (27).

So why are a majority of children not engaging in the recommended amount of physical activity? Several factors including age, sex, socioeconomic status, body mass index, ethnicity, parental support, and geographical location have been shown to contribute to the interindividual variation in physical activity levels among children (21). Another possible but often overlooked factor that may influence physical activity in children is motor skill performance. Given that fundamental motor skill development is one hypothesized impetus for participation in habitual physical activity, it seems essential to develop a wide base of fundamental motor skills during early to middle childhood to enhance the ability to participate in physical activity, particularly recreational sports settings (3,10,11,18,25). Even though the patterns of physical activity in childhood and adolescence are moderately predictive of lifelong physical activity patterns (26), skill-based activities contribute a large portion of children’s physical activity and may develop the impetus for future physical activity behaviors (11).

The interrelationships between physical activity, adiposity, and motor performance in children have previously been examined using bivariate relationships between either motor performance and adiposity (7,8,15,19) or motor performance and physical activity (6,8,18,20). Further, two studies (29,30) have examined the bivariate relationship between motor performance and physical activity and controlled for weight status (e.g., body mass index). In general, children with higher levels of adiposity display lower motor performance scores, and children with lower motor performance scores participate in less physical activity than peers with higher motor performance abilities. However, there is considerable variation in motor performance levels and physical activity among individuals with similar levels of adiposity.

In their conceptual model, Stodden and colleagues (24) suggest a “reciprocal and developmentally dynamic relationship between motor skill competence and physical activity.” This could be stated as an improvement in one causing an improvement in the other. However, in the Stodden model “unhealthy weight/obesity” is recognized as a potential outcome of poor motor skill competence and low physical activity levels, but this model fails to hypothesize if weight status modifies the relationship. Two studies (8,16) have investigated if weight status influences the association between physical activity and motor performance. Hume and colleagues (8) found those children with higher motor proficiency scores performed more physical activity; weight status did not significantly change this trend. More noteworthy, Morgan and colleagues (16) found correlations between 0.26 and 0.49 for gross motor quotient and physical activity levels of obese 5–9 year old boys and girls.

It seems reasonable to investigate both the joint association of adiposity and physical activity on motor performance as well as the joint association of adiposity and motor performance on physical activity in children. This analysis may provide further evidence to how the relationship between motor performance and physical activity is modified by weight status (e.g., level of adiposity). Thus, the purpose of
this investigation was threefold: 1) to determine the interrelationships (i.e., bivariate correlations) among physical activity, % body fat, and motor performance in 6- to 8-year-old Danish children, 2) to determine the joint association of % body fat and physical activity on motor performance, and 3) to determine the joint association of motor performance and % body fat on the level of physical activity.

Methods

Subjects

Subjects included in this analysis were tested during baseline data collection of the Copenhagen School-Child Intervention Study (4) from all 18 schools in 2 communities (Ballerup and Taarnby) within the Copenhagen area with similar sociodemographic characteristics. The local ethical committee at the University of Copenhagen approved the study. Written informed consent from the parents or guardian was mandatory before participation in the study. Of the 369 boys and 327 girls that originally provided parental consent to participate in the study, 498 children (265 boys, 233 girls, mean age 6.7 years) possessed complete data on all variables needed for the proposed research questions. There were no significant differences in age or other demographics between those subjects with complete or incomplete data. Data collection occurred between December 2001 and June 2002, which was before the initiation of the intervention.

Habitual Physical Activity

Habitual physical activity was assessed over four days (two weekdays, two weekend days) using the Actigraph (7164) accelerometer (ActiGraph LLC, Pensacola, FL). Due to the age of the participants and their potential to engage in spontaneous, short duration bouts of activity, a 10-s epoch was used. The participants were instructed to begin wearing the Actigraph one day before the actual beginning of recording to become accustomed to the device and prevent reactivity. Monitors were to be worn near the center of gravity on the lower back secured with an elastic belt. Participants were instructed to wear the Actigraph at all times except while sleeping and during activities involving water. Periods with zero counts lasting 10 min or longer were considered times that the Actigraph was not worn and were removed from the data file. For data to be used, a participant needed to accumulate a minimum of 8 hr of recorded activity on at least 3 of the 4 testing days. The average counts per 10-s epoch over the assessment period were calculated for each participant and used as the outcome variable in the data analysis. All units were calibrated in a motor driven vertical acceleration machine before use.

Anthropometry

Standing height was measured by a portable Harpenden stadiometer to the nearest 0.5 cm in bare feet using standard methodology. Body mass was measured to the nearest 0.1 kg using an electronic scale (Seca model 882, Hamburg, Germany) with the subjects lightly dressed. Assessments were conducted by experienced personnel following standard procedures. Intertester reliability ranged from 0.83
to 0.99. Body mass index (BMI, kg/m²) was calculated for each subject. Skinfold thickness was assessed at the triceps and subscapular skinfolds in triplicate on the nondominant side of the body using a Harpenden caliper. The average of the three values was taken from each site and converted to percent (%) body fat using the Slaughter equation (23).

Motor Performance

Motor performance was assessed by the Koordinations Test für Kinder (KTK; 22) as well as a test of throwing accuracy. The KTK is a product-oriented motor performance battery which consists of four age-adjusted movement ability tests: 1) a single-legged hop over obstacles, 2) a balance test on three different width beams, 3) a sideward jumping (ski jumping) test lasting 15 s, and 4) a lateral movement test lasting 20 s where the participant moves from one 6 × 6 inch footstool to another as many times as possible. A motor quotient for each participant was derived from the sum of the KTK age-adjusted scores from the four test items. In addition, a throwing accuracy test was performed by having participants stand three meters from a 35 cm wide square target. The target was placed 1.5 m above the floor. Subjects threw a tennis ball at the target ten consecutive times. The center (10 cm wide), middle (20 cm wide), and outer (35 cm wide) squares received three, two, and one points, respectively. The highest attainable score was thirty points. The test was first described in the Allgemeiner sportmotorischer Test für Kinder (AST) test battery (2). The throwing accuracy scores and KTK tests were added together to derive an overall motor performance score.

Statistical Analysis

Descriptive statistics were calculated for all variables, and independent samples t tests were used to examine gender differences. Pearson correlation coefficients were used to examine the associations among physical activity, % body fat, and motor performance for boys and girls separately. Gender-specific median splits were performed for each of the variables to examine purposes 2 and 3 of this study (i.e., joint association). Median values for the variables were: physical activity (boys = 125.0 counts/epoch, girls = 114.9 counts/epoch), % body fat (boys = 12.6%, girls = 14.8%), and motor performance score (boys = 115.5, girls = 113.5). To examine the joint association of % body fat and physical activity on motor performance—the following groups were created based on values equal to or above the median and those below the median: Low body fat/High physical activity, Low body fat/ Low physical activity, High body fat/ High physical activity, High body fat/Low physical activity. To examine the joint association of motor performance and % body fat on the level of physical activity—the following groups were created based on values equal to or above the median and those below the median: Low body fat/ High motor performance, Low body fat/ Low motor performance, High body fat/ High motor performance, High body fat/Low motor performance. Gender-specific analyses of covariance (ANCOVA), controlling for age, were performed to test for differences among the four groups described above for purposes 2 and 3 (e.g., combined influence). All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, Inc., Chicago, Ill.; version 16.0).
Results

Descriptive characteristics of the sample by gender are shown in Table 1. The mean stature, weight, and BMI for boys and girls fell between the 50th and 75th percentiles of the CDC growth chart (9). Significant differences ($p < .05$) existed between genders for age, height, weight, % body fat, and physical activity. Motor performance did not differ between boys and girls.

The interrelationships among physical activity, % body fat, and motor performance are shown in Table 2. Overall, correlations were low to moderate at best ($r < .36$, $p < .001$). Physical activity was not significantly correlated with % body fat and approximated zero ($r = .01$ to $-.06$, $p > .05$). Physical activity was significantly correlated with motor performance in boys ($r = .20$, boys; $p < .001$), but not girls ($r = .10$, $p > .05$). Further, when controlling for % body fat, the correlations between physical activity and motor performance were significant in both boys and girls ($r = .21$ and 0.14, respectively; $p < .05$), although coefficients remain comparable to when adiposity was not statistically controlled. The correlations between % body fat and motor performance were the highest among the three relationships examined ($r = -.35$, boys, $p < .01$; $r = -.23$, girls, $p < .001$), and remained similar when controlling for physical activity.

Figure 1 shows the joint association of % body fat and physical activity on motor performance scores in boys and girls, respectively. Boys and girls with lower % body fat had significantly higher motor performance than boys and girls with higher % body fat [(122 ± 2 v. 110 ± 2; $p = .0001$) and (115 ± 2 v. 110 ± 2; $p = .05$), respectively]. Further, boys and girls with higher physical activity had significantly higher motor performance than boys and girls with lower physical activity [(120 ± 2 v. 112 ± 2; $p = .006$) and (117 ± 2 v. 108 ± 2; $p = .003$), respectively]. Overall, there was a significant difference in motor performance across the four % body fat/physical activity groups in both boys and girls ($p < .001$). Boys and girls with higher % body fat and low levels of physical activity (i.e., high fat/low PA) had significantly lower motor performance scores than subjects in the other three groups ($p < .05$). It should be emphasized that within the high fat groups for both genders, those with higher level of physical activity had a significantly higher motor performance score; however, this was not shown within the low fat groups.

Table 1  Descriptive Characteristics of the Sample by Gender

<table>
<thead>
<tr>
<th></th>
<th>Boys (n = 265)</th>
<th>Girls (n = 233)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>6.8 (0.4)*</td>
<td>6.7 (0.4)</td>
</tr>
<tr>
<td>Ht (cm)</td>
<td>123.8 (4.9)*</td>
<td>122.0 (4.8)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>24.5 (3.6)*</td>
<td>24.0 (3.6)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>16.0 (1.7)</td>
<td>16.0 (1.8)</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>13.6 (4.1)*</td>
<td>15.7 (4.1)</td>
</tr>
<tr>
<td>Physical Activity (counts/10-s epoch)</td>
<td>129.8 (36.9)*</td>
<td>116.2 (26.6)</td>
</tr>
<tr>
<td>Motor Performance Score</td>
<td>115.7 (24.2)</td>
<td>113.0 (22.8)</td>
</tr>
</tbody>
</table>

* $p<.05$ between sexes
Table 2  Partial Correlations Between Physical Activity, Body Fat and Motor Performance Among 6- to 8-Year-Old Danish Children

<table>
<thead>
<tr>
<th></th>
<th>Boys (n = 265)</th>
<th></th>
<th>Girls (n = 233)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( r^a )</td>
<td>( r^b )</td>
<td>( r^a )</td>
<td>( r^b )</td>
</tr>
<tr>
<td>Physical activity &amp; % body fat</td>
<td>-.06</td>
<td>.04</td>
<td>.01</td>
<td>.05</td>
</tr>
<tr>
<td>Physical activity &amp; motor performance</td>
<td>.20***</td>
<td>.21***</td>
<td>.10</td>
<td>.14*</td>
</tr>
<tr>
<td>% body fat &amp; motor performance</td>
<td>-.35**</td>
<td>-.36***</td>
<td>-.23***</td>
<td>-.25***</td>
</tr>
</tbody>
</table>

* p-value <.05 ** p-value <.01 *** p-value<.001

\( r^a \) partial correlations controlling for age, \( r^b \) partial correlations controlling for age as well as the third dependent variable within the original correlation matrix.

Figure 1 — Differences in motor performance score by fat-physical activity groups. See results section for group differences.
Boys with lower body fat and high physical activity (low fat/high PA) showed significantly higher motor performance scores than their high activity peers with high body fat ($p < .05$).

Figure 2 shows the joint association of % body fat and motor performance on physical activity in boys and girls, respectively. There was no difference in physical activity between low and high % body fat groups for boys and girls (130 ± 3 v. 129 ± 3; $p > .05$) and (113 ± 2 v. 119 ± 2; $p = .09$), respectively. However, boys and girls with higher motor performance had higher physical activity than boys and girls with lower motor performance (136 ± 3 v. 123 ± 3; $p = .005$) and (119 ± 2 v. 113 ± 2; $p = .07$), respectively. Significant differences in physical activity were found between all % fat/motor performance groups in both boys ($p < .03$) and girls ($p < .003$); however, specific group differences were inconsistent between the sexes. In boys, within a body fat category those with higher motor performance scores showed higher levels of physical activity. Although significant in the low body fat groups ($p < .05$), there was only a nonsignificant trend between the 2 groups classified as high body fat ($p = .10$). In addition, there was a trend ($p = .09$) for boys with low fat/low MP to have lower physical activity compared with boys with high fat/high MP. This same group comparison (low fat/low MP v. high fat/high MP) was statistically significant ($p = .016$) in girls, and was the only significant group difference in girls (Figure 2).

**Figure 2** — Differences in physical activity by fat-motor performance groups. See results section for group differences.
Discussion

The present study is unique in that it examined the joint association of physical activity and body fatness on motor performance and the joint association of motor performance and body fatness on physical activity. In addition, we controlled for the concomitant variable in correlation analyses (e.g., controlling for physical activity when examining correlation between body fat and motor performance). These approaches are important to better understand the complex interrelationships among these variables. The results indicate low to moderate associations between physical activity and motor performance and body fatness and motor performance. Furthermore, motor performance is associated with physical activity regardless of the level of body fatness. Among boys and girls classified as high fat in this sample those with higher levels of physical activity performed better on the motor performance tasks.

In general, the positive correlations between physical activity and motor performance in this study are similar in magnitude to previous papers (6,8,18,20,29,30). As shown here, others have also reported either correlations or group differences (active v. inactive). In the current study, we grouped subjects by the median split and showed significant differences. Previously, Graf et al. (7) showed a significant graded relationship across five leisure behavior groups classified by parental questionnaire (no sport, irregular sport, regular sport, club sport, or club sport and regular sport) and KTK- motor performance quotient score among 668 German first graders.

A limitation of this study is the cross-sectional design that does not allow for the establishment of time-order between physical activity and motor performance. To our knowledge, there are only two longitudinal studies published on this topic (1,13). One study (1) identified that object control proficiency during childhood was positively associated with time spent in moderate to vigorous physical activity during adolescence, accounting for 12.7% of the variance in a group of Australian students. However, the results of a study by McKenzie and colleagues (13) indicated that motor performance between the ages of 4–6 years of age was not a significant predictor of adolescent physical activity in a sample of 207 Mexican American and Anglo American children. However, these studies used self-reported recall instruments to assess physical activity instead of an objective instrument such as accelerometry.

Several of the papers (1,8,16,20,29) that examined the bivariate relationship between motor performance and physical activity generally reported that a greater percentage of the explained variance in physical activity was due to object-control skills than locomotor skills, but this trend varied by gender. Therefore, another limitation of this study is that the overall motor performance score is not comprehensive in nature, relying primarily on balance and coordination skills, as well as one accuracy based object-control test to represent each subject’s motor abilities. Future research examining this topic using a longitudinal approach and a more comprehensive motor performance battery is warranted.

Compared with the literature on physical activity and motor skill performance, fewer papers have examined the relationship between adiposity and motor performance. Our findings are consistent with previous studies (7,15,19) in that youth with higher levels of adiposity possess lower motor performance scores. In a study that
also used the KTK to assess motor performance among 668 (341 boys, 327 girls) German first graders, Graf et al. (7) found a low correlation ($r = -0.16$) between motor performance quotient and BMI. We found a partial correlation (controlling for age and physical activity) of -0.35 in boys and -0.25 in girls between % body fat calculated from skinfold thickness and KTK motor performance. Others have shown the motor performance abilities of overweight youth were significantly lower when compared with normal weight youth from Bavaria (15) and Australia (19). Wearing and colleagues (28) have suggested that overweight children display poorer motor performance due to poor postural balance and insufficient muscular strength. Future studies exploring the neuro-mechanical mechanisms of this relationship would add to our understanding of this observation.

A primary aim and unique aspect of this paper was to examine the joint associations of % body fat and physical activity on motor performance and % body fat on the level of physical activity. The premise of this research question stems from the recognition that not all children with higher levels of fatness display poor motor skills and/or are physically inactive. The results indicate that for boys and girls within the high fat groups, those with higher level of physical activity had a significantly higher motor performance score. However, it is important to highlight that the median split was 13% body fat in boys and 15% body fat in girls; thus, the “high fat” group was still relatively lean compared with cutpoints used for overfatness (e.g., FITNESSGRAM, 32% girls and 25% boys). A previous study (16) sheds some light onto extending these results to overweight and obese children. Morgan et al. (16) showed that motor skill proficiency was significantly correlated ($r = .24–0.53$) with moderate and vigorous physical activity in obese 5–9 year old boys and girls. Object-control skill proficiency explained 10% of the variance in vigorous intensity physical activity and 25% of the activity counts per minute performed by boys; these values are some of the highest currently presented in the literature on this topic.

In summary, this study expands our knowledge of the joint association of adiposity on motor skill performance and also demonstrates a difference in physical activity patterns of children classified as “high fat” with low and high motor performance abilities. Although this study needs to be replicated in a sample of overweight and obese children, the results provide some insight into the inclusion of motor skill training as a component of a physical activity intervention for overweight children. Although physical activity is a key component of childhood obesity programs, the child must possess the requisite motor skills to successfully enjoy participation in most forms of physical activity and sport. Furthermore, it provides evidence for the necessity of a strong foundation of motor skill performance in relation to a physically active lifestyle for all children. However, this study and previous studies on this topic have been limited by its cross-sectional design. Future studies need to employ a longitudinal design to fully understand the complex interactions of physical activity, adiposity, and motor skill performance in children.

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References


