Relationship Between Motor Skill and Body Mass Index in 5- to 10-Year-Old Children

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The purpose of this study was to investigate gross and fine motor skill in overweight and obese children compared with normal-weight peers. According to international cut-off points for Body Mass Index (BMI) from Cole et al. (2000), all 117 participants (5–10 year) were classified as being normal-weight, overweight, or obese. Level of motor skill was assessed using the Movement Assessment Battery for Children (MABC). Scores for balance ($p < .01$) and ball skills ($p < .05$) were significantly better in normal-weight and overweight children as compared with their obese counterparts. A similar trend was found for manual dexterity ($p < .10$). This study demonstrates that general motor skill level is lower in obese children than in normal-weight and overweight peers.

Childhood obesity is a growing epidemic. Prevalence levels of overweight and obesity are dramatically increasing among children worldwide (Ogden et al., 2006; World Health Organization, WHO, 2000). The global prevalence of childhood overweight for 2010 is already estimated at 46% in the Americas and at 38% in the European region (Wang & Lobstein, 2006). This increase is alarming because obesity related health risks and psychosocial consequences are no longer only seen in adults (Daniels, 2006). Several adverse health outcomes (e.g., hypertension, high cholesterol, type II diabetes, the development of cardiovascular disease, orthopedic abnormalities, sleep apnea) are already associated with childhood obesity too (Burke, 2006; Daniels, 2006; Must & Strauss, 1999). In the long term, obese children are more likely to become obese adults, exposed to an increased comorbidity and mortality risk (Bray, 2004; Guo, Wu, Chumlea, & Roche, 2002).

Physical fitness of overweight and obese children has extensively been documented. Numerous studies already established a negative relationship between excessive body mass and performances on both endurance and weight-bearing tasks, whereas flexibility does not seem to differ significantly between overweight and normal-weight children.
or obese children and normal-weight peers (Casajús, Leivia, Villarroya, Legaz, & Moreno, 2007; Deforche et al., 2003; Graf et al., 2004, 2005, 2007; Tokmakidis, Kasambalis, & Christodoulou, 2006). Absolute handgrip strength even appears to be better in obese children and adolescents, given their increased fat-free mass (Casajús et al., 2007; Deforche et al., 2003). With respect to the relationship between movement coordination and childhood overweight, findings are somewhat contradictory. Using a single test item (lateral jumping) from the “Körperkoordinationstest für Kinder” (KTK; Kiphard & Schilling, 1974), Graf et al. (2004, 2005, 2007) concluded that overweight and obese children show whole body coordination deficits. Yet, the KTK consists of four interdependent tests to evaluate children’s general dynamic coordination. In contrast, Casajús et al. (2007) and Deforche et al. (2003) fully completed the European physical fitness test battery (Eurofit; Adam, Klissouras, Ravazzolo, Renson, & Tuxworth, 1988) and demonstrated that limb coordination in itself is not really impaired. Such inconsistent findings may be due to the tests being used and can be partially explained by the amount of body mass involved in the action. Although overweight and obese individuals do not produce lower scores on all fitness components, it is clear that they have inferior performances on physical tests requiring propulsion or lifting of the body mass.

As opposed to the knowledge on physical fitness, motor competence in overweight and obese children has only been investigated in a limited number of studies. The scarcity of information about motor competence in overweight and obese children contrasts with the potential importance of this factor in both development and treatment of the epidemic (Cairney, Hay, Faught, & Hawes, 2005; Okely, Booth, & Chey, 2004). Motor competence can be defined as a person’s movement coordination quality when performing different motor skills, ranging on a continuum from gross to fine motor skills. Nevertheless, the majority of available studies on motor skill competence in overweight and obese children focus exclusively on gross motor skills, like balance and gait. In laboratory settings as well as in standardized field tests, it has been shown that overweight and obese boys display impaired performances on several static and dynamic postural skills (Deforche et al., 2006; Goulding, Jones, Taylor, Piggot, & Taylor, 2003). Similarly, McGraw, McClenaghan, Williams, Dickerson, and Ward (2000) demonstrated that obese prepubertal boys have significantly greater sway areas while standing upright. Given the importance of dynamic balance in locomotion, it is no surprise that also walking gait patterns of obese children are different in that single and double support phases are longer (Hills & Parker, 1991, 1992). Studies from Marshall and Bouffard (1994), Okely et al. (2004), and Southall, Okely, and Steele (2004) found body composition to be negatively related to locomotor skill proficiency (e.g., running, jumping) but did not reveal differences in motor skill level for relatively stationary object control tasks (e.g., striking, throwing, catching, kicking). Concerning movement skills demanding fine motor proficiency (e.g., drawing, manipulating small objects), detailed information is lacking.

Because excessive body weight affects body geometry and increases the mass of different body segments, the observed differences in motor skill are primarily explained from a mechanical point of view; however, evidence for such an exclusive explanation is limited. In fact, there are several alternative mechanisms that may lead to inferior motor performances in overweight and obese children. Previ-
ous studies have already shown that a lower socioeconomic status (SES) could be related to obesity (Rosengren & Lissner, 2008; Shrewsbury & Wardle, 2008; Stamatakis, Primatessa, Chinn, Rona, & Falaschetti, 2005) and is likely to be associated with lower levels of gross and especially fine motor skill performance as well (Bobbio, Morcillo, Barros, & Gimenes Gonçalves, 2007; de Barros, Fragoso, de Oliveira, Cabral, & de Castro, 2003). In addition, research has shown more obesity in a group of children with Developmental Coordination Disorder (DCD; Cairney, Hay, Faught, & Hawes, 2005). There are also studies bringing forward an activity deficit hypothesis, indicating that children with movement difficulties are less likely to participate in organized and free play activities, because they perceive themselves less competent than other children (Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996; Cairney et al., 2005; Cairney, Faught, Corna, & Flouris, 2006). Because previous studies already suggested that obese children show poorer motor behavior when sensory information is needed to plan and control movement (Bernard et al., 2003; Petrolini, Iughetti, & Bernasconi, 1995), the hypothesis of a perceptual-motor deficit cannot be excluded at this time either.

Motor skill of overweight and obese children has not yet been extensively documented, and the focus in the available studies is primarily on gross motor skills. Moreover, present indications for an inverse relationship are generally explained from a mechanical point of view, as the relation seems to fade when less body mass is involved in the task at study. Therefore, the primary purpose of this study was to investigate both gross and fine motor skills in overweight and obese children compared with normal-weight peers. To achieve this objective, children’s motor skill competence was tested by means of a movement assessment battery covering the whole spectrum of motor skill. We wanted to verify if differences in motor skill competence between normal-weight, overweight, and obese children would also appear if only a limited part of the body mass is involved in the action, and thus test to see to what extent alternate explanations may hold. Because several previous studies only focused on boys, gender differences were also examined.

Method

Participants

A total of 117 children between the age of 5 and 10 years (61 normal-weight, 22 overweight, 34 obese; 60 girls and 57 boys) participated in this study. One hundred and four children had either one or both parents with the Belgian nationality, whereas parents of one participant were both Dutch and three children had Turkish parents. Data about parental nationality were missing for 9 participants. Familial SES of each participant was estimated on the basis of parent’s educational level. Fifty-two participants had either one or both parents that were completing postsecondary education or had already done so (high SES), whereas parents of 53 participants were completing or had completed a lower level of education (low SES). Data on both parents’ educational level were lacking for 12 children out of the sample.

For each participant, informed consent was signed by both the parents and the school or revalidation center staff. Approval for this study was obtained from the
Ethical Committee of the Ghent University Hospital, and treatment of the participants was in accordance with the ethical principles of the American Psychological Association (APA).

**Procedure and Materials**

Ten schools located in East and West Flanders, two Flemish provinces, contributed to this study. Parents of the children were informed about the study. If they volunteered to participate, they were asked to report their nationality and educational level as well as the stature and body mass of their child. From these latter self-reported data, BMI was calculated for each participant according to the international cut-off points from Cole, Bellizzi, Flegal, and Dietz (2000) to have a provisional idea of the number of children with overweight or obesity. When a child was identified as being overweight or obese, a schoolmate with the same gender and age (within the range of six months) was selected to be a control child. Eleven children from the sample were residents in the Revalidation Centre (RC) Zeepreventorium (De Haan, Belgium). Yet, those children were assessed at the beginning of their stay so that the followed multidisciplinary treatment program could not influence the outcome of our measurements.

At a single test moment in a quiet room at the children’s respective schools, anthropometric measures were collected first. Subsequently, children were tested on the Movement Assessment Battery for Children (MABC). The assessment of motor skill was executed in accordance with the MABC manual (Henderson & Sugden, 1992). During the following seven days, physical activity levels were determined by accelerometry.

**Anthropometry.** Stature was measured barefoot to the nearest 0.1 cm using a portable stadiometer. Participants were asked to stand with back, buttocks, and heels against the stadiometer, with their feet together and flat on the floor and their head straightened in a neutral position. Body mass was measured in minimal clothing and to the nearest 0.1 kg using a digital balance scale (SECA Model 812, Vogel & Halke, Hamburg, Germany). From those two measurements, BMI, weight(kg)/height(m)^2 was calculated for each participant.

A wide range of definitions for overweight and obesity in adults and children are available. In this study, BMI was used to identify overweight and obese children because of its practical advantages and its strong correlation with more direct adiposity measures derived from dual energy X-ray absorptiometry (DEXA; Lindsay et al., 2001). According to the international cut-off points for BMI in children from Cole et al. (2000), participants were classified as being normal-weight, overweight, or obese. The International Obesity Task Force (IOTF) has developed those calendar age- and gender-specific BMI cut-off points for overweight and obesity in children using data specific percentile curves linked to the health risk related adult cut-off points of 25 kg/m^2 and 30 kg/m^2. The IOTF cutoffs have been recommended for international use and are widely accepted since then (Wang & Wang, 2002). BMI z-scores were calculated on the basis of Flemish reference data (Roelants & Hauspie, 2004) using the LMS method, which summarizes data in terms of three smooth age-specific curves called L (lambda), M (mu), and S (sigma; Cole, 1990; Cole & Green, 1992). The BMI z-score provides
a relative age- and gender-specific measure of adiposity as it is the number of standard deviation units that a person’s BMI is above or below a mean or reference value.

**Motor Skill.** Motor skill was assessed by means of the Movement Assessment Battery for Children (MABC; Henderson & Sugden, 1992). In this study the Dutch version of the MABC was used (Smits-Engelsman, 1998). The MABC consists of eight age-specific test items, brought together in three clusters (manual dexterity, ball skills, and static and dynamic balance) as shown in Table 1. For each test item a raw performance score is converted into a scaled score ranging between 0 and 5. Summation of these scores results in three cluster scores (range 0–10 or 0–15) and a total MABC score (range 0–40), with a lower score representing a better performance. Based on the percentile norm tables of a Dutch standardization sample, the total MABC score of each child can also be converted into a percentile score.

Test-retest reliability of the total MABC score is considered to be high \((r = .95)\) over a one-week period across all age bands (Croce, Horvat, & McCarthy, 2001) and good \((r = .88)\) over a three-week period between three consecutive assessments for 4- and 5-year-old children (Van Waelvelde, Peersman, Lenoir, & Smits-Engelsman, 2007b). The MABC is also featured by a good concurrent and convergent validity (Croce et al., 2001; Van Waelvelde, Peersman, Lenoir, & Smits-Engelsman, 2007a).

**Physical Activity.** Physical activity (PA) was assessed using accelerometers (model 7164, Computer Science Application, CSA, Inc., Shalimar, FL) during the seven days following the test moment at the school. The accelerometer has been

### Table 1  Test Items for Age Band 1, 2, and 3 of the Movement Assessment Battery for Children (MABC)

<table>
<thead>
<tr>
<th></th>
<th>AGE BAND 1 4–6 years</th>
<th>AGE BAND 2 7–8 years</th>
<th>AGE BAND 3 9–10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual dexterity</td>
<td>Posting coins</td>
<td>Placing pegs</td>
<td>Shifting pegs by rows</td>
</tr>
<tr>
<td></td>
<td>Threading beads</td>
<td>Threading lace</td>
<td>Threading nuts on bolt</td>
</tr>
<tr>
<td></td>
<td>Bicycle trail</td>
<td>Flower trail</td>
<td>Flower trail</td>
</tr>
<tr>
<td>Ball skills</td>
<td>Catching bean bag</td>
<td>One-hand bounce and catch</td>
<td>Two-hand catch</td>
</tr>
<tr>
<td></td>
<td>Rolling ball into goal</td>
<td>Throwing bean bag into box</td>
<td>Throwing bean bag into box</td>
</tr>
<tr>
<td>Static and dynamic balance</td>
<td>One-leg balance</td>
<td>Stork balance</td>
<td>One-board balance</td>
</tr>
<tr>
<td></td>
<td>Jumping over cord</td>
<td>Jumping in squares</td>
<td>Hopping in squares</td>
</tr>
<tr>
<td></td>
<td>Walking heels raised</td>
<td>Heel-to-toe walking</td>
<td>Ball</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>balance</td>
</tr>
</tbody>
</table>
shown to be a valid and reliable tool for the assessment of PA in children (Janz, 1994; Puyau, Adolph, Vohra, & Butte, 2002; Trost et al., 1998).

Children were requested to wear the accelerometer above the right hipbone, underneath their clothes. Accelerometers were held in place with an elastic belt and adjustable buckle. The children were asked to take the accelerometer off in situations where they could hurt themselves wearing the activity monitor (e.g., contact sports). As the activity monitor is not waterproof, it was also put off for water activities (e.g., swimming, taking a bath or shower).

The accelerometers were set to measure activity counts in an epoch time of one minute. Activity counts are the summation of the accelerations measured over the epoch. A distinction was made between minutes of less than 800 counts, 801–3,199 counts (less than 2.99 METs, metabolic equivalents), 3,200–8,199 counts (3.0–5.99 METs) and more than 8,200 counts (more than 6.0 METs), corresponding respectively to inactivity, activity of light, moderate, and high intensity (Puyau et al., 2002). Days with less than 600 min (or 10 hr) registered time and participants with less than three valid days (including one weekend day) were excluded from further analyses. Children from the RC Zeepreventorium did not wear an accelerometer and one accelerometer was lost. Hence, PA data from 87 children out of the total sample could be used in our statistical analysis.

**Statistical Analysis**

To compare anthropometric and demographic variables between BMI-groups, one-way analyses of variance (ANOVAs) or Pearson \( \chi^2 \) analyses were conducted. To investigate differences in MABC scores, two-way ANCOVAs (analyses of covariance) were undertaken with BMI-group and gender as fixed factors, while age was inserted as a covariate. When necessary, scores of BMI-groups were further examined with Fisher least significant difference (LSD) tests. Pearson correlation coefficients were also calculated to examine the mutual relationship between BMI z-scores and MABC scores. A Pearson \( \chi^2 \) analysis was used to have a closer look at the children within each BMI-group that were situated at, below, or between the 5th and 15th percentile MABC cut-off points. Furthermore, one-way ANCOVAs (age included as a covariate) were conducted to compare MABC scores of participants with a different familial SES. To test correlation between motor skill performance and PA, Pearson correlation coefficients were calculated.

Data were analyzed using the statistical package SPSS 15.0 for Windows. Results are mainly presented as means (\( M \)) with standard deviations (\( SD \)) and \( F \)-, \( \chi^2 \)-, or \( r \)-values. Values of \( p < .05 \) were considered as statistically significant and values of \( p < .10 \) as a trend for statistical significance.

**Results**

**Descriptive Statistics**

Based on the cut-off points for BMI from Cole et al. (2000), a classification into three BMI-groups was applied: normal-weight (52.1%), overweight (18.8%), and obese (29.1%). In accordance with that classification, anthropometric...
Table 2  Means, Standard Deviations and BMI-Group Main Effects for Age, Height, Weight, and BMI

<table>
<thead>
<tr>
<th>Anthropometric Variables</th>
<th>NW (n = 61)</th>
<th>OW (n = 22)</th>
<th>OB (n = 34)</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (year)</strong></td>
<td>M 8.5</td>
<td>8.7</td>
<td>8.4</td>
<td>0.33</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>SD 1.4</td>
<td>1.3</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>M 131.8</td>
<td>136.4</td>
<td>136.5</td>
<td>3.15*</td>
<td>&lt; .05</td>
</tr>
<tr>
<td></td>
<td>SD 9.5</td>
<td>8.8</td>
<td>11.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>M 27.5&lt;sub&gt;a&lt;/sub&gt;</td>
<td>39.1&lt;sub&gt;b&lt;/sub&gt;</td>
<td>50.7&lt;sub&gt;c&lt;/sub&gt;</td>
<td>60.34**</td>
<td>&lt; .01</td>
</tr>
<tr>
<td></td>
<td>SD 5.4</td>
<td>6.4</td>
<td>16.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>M 15.7&lt;sub&gt;a&lt;/sub&gt;</td>
<td>20.9&lt;sub&gt;b&lt;/sub&gt;</td>
<td>26.6&lt;sub&gt;c&lt;/sub&gt;</td>
<td>150.72**</td>
<td>&lt; .01</td>
</tr>
<tr>
<td></td>
<td>SD 1.5</td>
<td>1.4</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. N = 117. NW = normal-weight; OW = overweight; OB = obese. Means with different subscripts differ significantly at p < .01 by the Fisher least significant difference (LSD) test.*

*p < .05. **p < .01.
characteristics are presented in Table 2. With 19 children in age band 1 (4–6 years), 50 children in age band 2 (7–8 years), and 48 children in age band 3 (9–10 years); mean age of the total sample was set at 8.5 ± 1.4 years. Within each BMI-group mean age, \( F(2, 114) = .33, p = .72 \), as well as the proportion of girls and boys, \( \chi^2(2, N = 117) = .67, p = .72 \), were approximately the same. With regard to height, \( F(2, 114) = 3.15, p < .05 \), Fisher LSD tests revealed a tendency for obese children to be somewhat taller compared with the children in the normal-weight group \( (p = .08) \). Logically, weight, \( F(2, 114) = 60.34, p < .01 \) and BMI, \( F(2, 114) = 150.72, p < .01 \), were higher among obese children compared with both other BMI-groups \( (p < .01) \), while overweight children were heavier \( (p < .01) \) and had a higher BMI \( (p < .01) \) than their normal-weight peers. Furthermore, Pearson \( \chi^2 \) analysis, \( \chi^2(2, N = 105) = 9.84, p < .01 \), showed that the greater part of overweight \( (61.9\%) \) and obese children \( (72.0\%) \) had a low familial SES, whereas most normal-weight participants \( (62.7\%) \) were compromised in the high SES-group.

### MABC Scores in Relation to BMI and Gender

The main results regarding MABC scores are shown in Table 3. Gender did not significantly interact with BMI-group for any of the scores mentioned and no main gender effect occurred. However, a main effect of BMI-group in itself was shown. Absolute cluster scores always appeared to be better in normal and overweight children compared with their obese counterparts. Scores for ball skills \((p < .05)\) and static and dynamic balance \((p < .01)\) were significantly better, while a trend was found for manual dexterity \((p < .10)\). There was also a similar effect of BMI-group on the total MABC score \((p < .01)\). Again, Fisher LSD tests revealed that children in the obese group performed worse than those in both other BMI-groups.

To investigate the relationship between BMI z-scores and MABC scores, Pearson correlation coefficients were calculated (see Table 4). While only a trend was found for the manual dexterity cluster score \((p < .10)\), all other MABC scores were significantly and adversely correlated to BMI z-score. Regarding static and dynamic balance \((p < .01)\) approximately 20% of the variance in cluster score could be explained by BMI status of the children. For the ball skills cluster score \((p < .05)\) and total MABC score \((p < .01)\), BMI z-score accounted for 3.9% and 11.8% of the variance in performance respectively.

From a diagnostic point of view, it was worthwhile to have a closer look at the percentage of children within each BMI-group scoring at or below the 5th percentile and the percentage of children scoring between the 5th and 15th percentile on the MABC. In that case, children are considered to have a definite motor problem or to be a child at risk, respectively. Frequency comparisons were made by Pearson \( \chi^2 \) (see Table 5). The results within the obese group were remarkable: 26.5% had a total MABC score at or below the 5th percentile, and 17.6% scored between the 5th and 15th percentile. With respect to those MABC cut-off points, percentages for the overweight and normal-weight group were quite lower.
Table 3  Means, Standard Deviations and BMI-Group Main Effects for MABC Scores

<table>
<thead>
<tr>
<th>MABC Scores</th>
<th>NW (n = 61)</th>
<th>OW (n = 22)</th>
<th>OB (n = 34)</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual dexterity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>2.1&lt;sub&gt;a&lt;/sub&gt;</td>
<td>2.2&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3.3&lt;sub&gt;b&lt;/sub&gt;</td>
<td>2.85&lt;sup&gt;(*)&lt;/sup&gt;</td>
<td>0.06</td>
</tr>
<tr>
<td>SD</td>
<td>2.4</td>
<td>2.4</td>
<td>2.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ball skills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>0.9&lt;sub&gt;a&lt;/sub&gt;</td>
<td>0.8&lt;sub&gt;a&lt;/sub&gt;</td>
<td>1.8&lt;sub&gt;b&lt;/sub&gt;</td>
<td>3.88*</td>
<td>0.02</td>
</tr>
<tr>
<td>SD</td>
<td>1.3</td>
<td>1.8</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static and dynamic balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>0.9&lt;sub&gt;a&lt;/sub&gt;</td>
<td>1.0&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3.8&lt;sub&gt;b&lt;/sub&gt;</td>
<td>22.31**</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>SD</td>
<td>1.4</td>
<td>1.9</td>
<td>3.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>3.9&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3.9&lt;sub&gt;a&lt;/sub&gt;</td>
<td>8.9&lt;sub&gt;b&lt;/sub&gt;</td>
<td>11.51**</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>SD</td>
<td>3.9</td>
<td>5.5</td>
<td>6.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. N = 117. NW = normal-weight; OW = overweight; OB = obese. Means with different subscripts differ significantly at p < .01 by the Fisher least significant difference (LSD) test.

<sup>(*)</sup> p < .10.  <sup>*</sup>p < .05.  **p < .01.
One-way ANCOVAs were conducted to compare MABC scores of participants with dissimilar SES backgrounds. Only for the balance cluster score, \( F(1,102) = 8.09, p < .01 \), a significant difference was shown, as children in the low SES-group (2.1 ± 2.7) performed worse than those in the high SES-group (0.9 ± 1.5). Scores for manual dexterity, ball skills and total MABC were not significantly different between both SES-groups.

### MABC Scores in Relation to PA

Pearson correlation coefficients were calculated for each MABC score with respect to daily average PA of moderate to high intensity per day, measured across a seven day period (see Table 6). With the exception of manual dexterity, all other cluster scores as well as the total MABC score were negatively correlated with moderate to high intensity PA at the .05 significance level (\( r \)-values between -.21 and -.25).

### Discussion

The primary purpose of this study was to investigate gross as well as fine motor skill in overweight and obese children compared with normal-weight peers. Group differences were expected to emerge in tasks involving the whole body, but we
also wanted to verify if these differences would persist when only a limited part of the body mass was involved in the action. Given that previous studies frequently focused on boys, possible gender differences in motor competence skill according to weight status were also examined.

Results demonstrated that childhood obesity is associated with lower total MABC scores. So next to their already extensively documented lower physical fitness, obese children also display poorer general motor skill performance. Against expectations, no differences in motor skill were found between normal-weight children and children who are overweight. This suggests the existence of a certain cut-off from which movement difficulties appear.

Scores of the obese group differed most from both other BMI-groups for the static and dynamic balance cluster (gross motor skill). Childhood overweight in itself did not seem to be related to inferior functional levels of static and dynamic balance when compared with normal-weight peers. These findings are thus in accordance with earlier studies demonstrating that obese boys have poorer outputs on balance and postural sway (Goulding et al., 2003; McGraw et al., 2000). Given that no gender differences were established in the current study, obese girls produced poorer balance cluster scores as well.

The same significant differences between BMI-groups were found for the ball skills cluster that combines fine motor control and balance control in an upright position. It has repeatedly been shown that in children a well controlled postural balance is beneficial for ball handling skills (Davids, Bennett, Kingsbury, Jolley, & Brian, 2000; Savelbergh, Bennett, Angelakopoulos, & Davids, 2005). Maintaining a stable postural orientation while moving the arm is thus suggested to be the requisite for successful ball manipulation rather than the control of the distal limb itself (Savelbergh et al., 2005). Berrigan, Simoneau, Tremblay, Hue, and Teasdale (2006) actually demonstrated that obesity imposes constraints on goal-directed movements, given its disadvantageous effect on the control of balance; however, studies by Marshall and Bouffard (1994), Okely et al. (2004), and Southall et al. (2004) did not find differences for object control skill proficiency according to body composition. The discrepancy between those results and the outcome of the current study might be explained by the use of different evaluation methods. Marshall and Bouffard, Okely et al., and Southall et al. were all using

Table 6  Correlations Between Physical Activity of Moderate + High Intensity and MABC Scores

<table>
<thead>
<tr>
<th>MABC Scores</th>
<th>PA_{mod+high}</th>
<th>r</th>
<th>r²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual dexterity</td>
<td>-.17(*)</td>
<td>0.03</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Ball skills</td>
<td>-.21*</td>
<td>0.05</td>
<td>&lt; .05</td>
<td></td>
</tr>
<tr>
<td>Static and dynamic balance</td>
<td>-.22*</td>
<td>0.05</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Total score</td>
<td>-.25*</td>
<td>0.06</td>
<td>0.02</td>
<td></td>
</tr>
</tbody>
</table>

*Note. N = 87. PA_{mod+high} = physical activity of moderate and high intensity.
* p < .05.
simple qualitative evaluations of the process or technique, while in the MABC, evaluation is based upon objective product scores (e.g., time in seconds, number of successful repetitions).

For the manual dexterity cluster, a tendency toward weaker performances of obese children compared with normal-weight and overweight counterparts was observed. The absence of an actual significant difference between BMI-groups may be because temporal and spatial constraints of the tasks are controlled by the child itself. In contrast, in the ball skills cluster of the MABC, most tasks are externally paced. Therefore, the child has to extract visual information on the spatial and temporal aspects of the object flight and needs to integrate this information in the ongoing action. The manual dexterity cluster of the MABC might not have enough discriminative power in this respect.

The inverse relationship between motor skill competence and body weight is often explained from a mechanical point of view, because obesity influences body geometry and increases the mass of different body segments. Hence, noncontributory mass could lead to biomechanical movement inefficiency and could be detrimental for motor proficiency. As differences in motor skill performance between BMI-groups were most obvious for skills involving more body segments, our results partially confirm this weight-bearing hypothesis. Nevertheless, we believe that the reported negative relationship between motor skill and BMI is mediated by several alternative, and possibly complementary, mechanisms.

Previous studies have already shown that a lower socioeconomic status (SES) could be related to obesity (Rosengren & Lissner, 2008; Shrewsbury & Wardle, 2008; Stamatakis et al., 2005). Likewise, we found that BMI values were significantly higher in children of the low SES-group. Besides, poor SES is likely to be associated with lower motor skill performance in children. Available data on this topic suggest that a low familial SES is an environmental risk factor for motor development, and especially for fine motor coordination (Bobbio et al., 2007; de Barros et al., 2003). Comparing MABC scores of participants with a different SES based on parental educational level in the current study revealed that children in the low SES-group only performed worse on the balance cluster. This finding is probably due to the difficulties of overweight and obese children to control balance, because prevalence levels of overweight and obesity were higher in the low SES-group.

From the point of motor developmental problems, Cairney et al. (2005) found more obesity in a group of children with DCD. In our sample, more than one quarter of the obese children (26.5%) had a total MABC score at or below the 5th percentile, and is thus considered to have a definite motor problem. Having a total MABC score between the 5th and 15th percentile, approximately one fifth (17.6%) of the obese children in this study was at risk for serious motor difficulties. Consequently, the proportion of children in these two diagnostic situations was systematically higher in the obese group. The fact that children with DCD are more likely to be overweight or obese than children without the disorder is probably contributing to these results.

As children with movement difficulties perceive themselves less competent than other children, they are less likely to be physically active and they show preference for sedentary pastime (Bouffard et al., 1996; Cairney et al., 2005, 2006). Such an activity deficit may however strengthen their lack of motor skill profi-
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ciency (Hands & Larkin, 2002). Withdrawal from physical activities surely inhibits diversified movement experiences and simultaneously opportunities promoting neuromotor development (Fisher et al., 2005; Wrotniak, Epstein, Dorn, Jones, & Kondillis, 2006). At the same time, physical inactivity contributes to a positive energy balance and is therefore related to the current increase in childhood overweight and obesity (Abbott & Davies, 2004; Hills, King, & Armstrong, 2007; Page et al., 2005). An inactive lifestyle thus may bring the obese child into a vicious circle, concerning both the health problem per se and the reported movement difficulties that seem to be related with it. In this respect, we found that daily average PA of moderate to high intensity was associated with poorer motor skill performances. Since earlier studies (Fisher et al., 2005; Graf et al., 2004; Wrotniak et al., 2006) demonstrated that PA is related to motor skill as well, it can be stated that children need to be sufficiently physically active to experience movement in all its aspects.

The occurrence of a tendency toward a weaker performance of obese children for manual dexterity is not conform to the mechanical point of view that is generally postulated to explain differences in motor skill related to weight status. Because all manual dexterity items from the MABC are performed while seated, no displacement of the extra body mass is needed, and balance control is not challenged to a great extent. Still, fine motor skill performance of obese children seems to be inferior compared with normal-weight and overweight counterparts. This outcome raises the idea that obese children might suffer from perceptual motor coordination difficulties, because it was previously suggested they show poorer motor behavior when sensory information is needed to plan and control movement (Bernard et al., 2003; Petrolini et al., 1995). Nevertheless, the hypothesis of a perceptual-motor deficit in obese children is rather speculative and must therefore be addressed further, since specific evidence is currently lacking.

Limitations

Several limitations of the current study must be mentioned. First, no specific criteria were used to exclude participants from the study. For example, parents were not asked for information with regard to the term of gestation or the birth weight of their child. Yet, premature and low birth weight children are frequently characterized as having perceptual and motor deficits. Participants were not screened for possible neuromuscular or neurological dysfunctions either. Further studies with solid exclusion criteria are therefore needed to replicate and expand our findings. Second, because a MABC cluster only contains a limited number of tests, it is important to recognize that reliability of the MABC cluster scores is somewhat lower than that of the total MABC score. Interpretation of the cluster scores thus needs to be done with certain caution. Third, due to the cross-sectional design, no causality can be established from the data, so no conclusion can be drawn as to whether childhood obesity leads to poorer motor skills or whether children became obese because of their lower motor skill level. Fourth, the study was not designed to really test the underlying mechanisms that might account for our results that support an inverse relationship between motor skill and BMI in children. In addition, the mutual dynamic interactions between all factors that are plausibly related to motor skill performance are still unknown.
**Recommendations for Future Research**

The inverse relationship between motor skill and weight status needs to be addressed further. The present findings are important because a lower level of motor skill may hamper participation in regular physical activities, which is an important factor in both prevention and treatment of childhood obesity; however, future research needs be done to confirm results of this study and to extend the conclusions to other populations as well. Besides, detailed kinematic analysis of obese children’s movement pattern can provide additional information to their performance on movement assessment batteries. Future studies should be designed to actually test for the accuracy of several underlying mechanisms that might explain lower motor skill in obese children. Finally, insight must be gained into how the relationship between motor skill and BMI in children is mediated by all those possibly complementary factors, in order to support therapeutic efforts.

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**References**


