Physical fitness and overweight in Israeli children with and without developmental coordination disorder: Gender differences

N. Lifshitz a,*, S. Raz-Silbiger b, c, N. Weintraub b, S. Steinhart c, S.A. Cermak d, N. Katz e

a Department of Occupational Therapy, Faculty of Health Professions, Ono Academic College, Israel
b School of Occupational Therapy, Hebrew University Jerusalem, Israel
c Alyn Hospital, Pediatric & Adolescent Rehabilitation Center, Jerusalem, Israel
d Division of Occupational Science and Occupational Therapy, College of Health Professions, University of Southern California, LA, USA
e Research Institute for Health and Medical Professions, Ono Academic College, Israel

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ABSTRACT

Physical fitness and overweight among children has become paramount in the general population and more so in children with developmental coordination disorder (DCD). The purpose of the current study was to examine the association between physical fitness and overweight in a sample of Israeli children in comparison to typical children, and to examine gender differences. DCD was identified through total scores on the movement assessment battery for children 2 (MABC-2) equal to or less than the 16th percentile as well as parents’ report that the child’s deficits in motor skills interfered with at least two daily life activities. The sample included a group of children with DCD ($n = 22$, $M$ age $= 8.70$ [SD $= 1.36$], 16 boys [73%]) and a control group of typical children ($n = 47$, $M$ age $= 8.90$ [SD $= 1.52$], 34 boys [72%]). Measures included the strength subtest of the Bruininks–Oseretsky test of motor proficiency (BOT-2), the six minutes’ walk test (6MWT) with heart rate measure, BMI and the percentage of body fat. Significant differences between DCD and typical children were found on all variables of physical fitness and weight. A two-way analysis of variance (ANOVA) analysis (group/gender) also revealed significant interactions for the percentage of body fat ($F = 8.51$, $p < .005$) and BMI ($F = 4.50$, $p < .038$) meaning that less fit children are more obese. The current study supports previous findings that children with DCD are less physically fit and more overweight compared to typically developing children. Moreover, in comparing between the genders, the girls in the study sample weighed more and had a significantly higher percentage of body fat than boys, it is essential to further our understanding of the relationships between obesity, physical fitness and gender among children with and without DCD.

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1. Introduction

Developmental coordination disorder (DCD) is a motor neurodevelopmental disorder characterized by clumsiness as well as slow, inaccurate performance of motor skills. A diagnosis of DCD is assigned only if the impairment in motor skills...
Studies show that children with DCD participate less in physical activities due to their motor difficulties (Beutum, Cordier, & Bundy, 2013; Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996; Cermak & Katz, 2013; Rivilis et al., 2011). Since physical activity provides fundamental health benefits for children and youths (World Health Organization, 2011a), the physical health of children with DCD has increasingly become a topic of interest (Chirico et al., 2012; Rivilis et al., 2011). Whereas some studies have focused on comparing the physical health of children with DCD with that of typically developing (TD) children worldwide, others have focused on the relationship between physical fitness and overweight among children with DCD in comparison to TD children (Beutum et al., 2013; Cairney et al., 2010; Faught, Demetriades, Hay, & Cairney, 2013; Rivilis et al., 2011; Tsiotra, Nevill, Lane, & Koutedakis, 2009; Zhu, Wu, & Cairney, 2011). The various studies present conflicting findings and the gender issue was mostly not considered.

Physical fitness refers to a set of attributes that are either health- or skill-related (Caspersen, Powell, & Christenson, 1985), and includes body composition, flexibility, strength, speed and cardiorespiratory fitness (Troost et al., 2009). Among other things, poor health-related physical fitness is an important risk factor for cardiovascular disease (Li, Wu, Cairney, & Hsieh, 2011). Studies have shown that on average, children with DCD have lower fitness levels compared to their TD peers (Li et al., 2011; Rivilis et al., 2011), with lower VO2 peaks (Burns et al., 2009; Chia, Guelfi, & Licari, 2010; Silman, Cairney, Hay, Klentrou, & Faught, 2011; Wu, Lin, Li, Tsai, & Cairney, 2010); lower aerobic fitness scores on the Léger 20 meter run (Cairney, Hay, Faught, Flouris, & Klentrou, 2007; Faught, Hay, Cairney, & Flouris, 2005); and lower endurance, flexibility and strength (Burns et al., 2009; Chia et al., 2010; Silman et al., 2011; Wu et al., 2010).

According to the World Health Organization (2011b) overweight and obesity are defined as an abnormal or excessive accumulation of fat that may impair health. Childhood obesity is associated with a higher chance of adult obesity, premature death and disability. In addition to increased future risks, obese children may experience breathing difficulties, increased risk of fractures, hypertension, and early markers of cardiovascular disease, insulin resistance and psychological effects.

Several studies have examined the relationship between DCD and overweight. Recently, Zhu et al. (2011) found that the prevalence of overweight and obesity among Taiwanese children aged 9–10 with DCD was higher than among children with TD. Similar results were found among children aged 7–11 in Australia (Beutum et al., 2013) and Canada (Cairney et al., 2010) and among school-aged children in Hong Kong (Fong et al., 2011). In a large-scale longitudinal study in Great Britain, Osika and Montgomery (2008) reported a significant association between teachers’ assessments of hand control, coordination, and clumsiness at age 7 and obesity at age 33. However not all studies showed significant differences in body mass index (BMI) between DCD and TD children in same-aged groups (7–11 years) in primary schools (Castelli & Valley, 2007; Hands, 2008; Wu et al., 2010).

According to Zhu et al. (2011), inconsistencies can be found with respect to gender differences in relation to the association between motor performance and obesity. In a large study of 578 children ages 9–14, Cairney, Hay, Faught, and Hawes (2005) found that DCD may be a risk factor for overweight/obesity among boys, but found no difference in the prevalence of overweight/obesity between children with and without DCD among girls. However in a later study, Cairney and colleagues (2010) found no evidence of interaction between gender and overweight or obesity among children with possible DCD. Furthermore, in a study by Zhu et al. (2011) in which groups of normal-weight, overweight and obese children were examined, more boys with DCD were found in the obese group than in the other two groups. Results differed for the girls in the sample, such that there was a higher prevalence of girls with DCD in both the overweight and obese groups than in the normal-weight group. Other researchers reported that obese boys performed gross motor skills more poorly than normal-weight boys. However, these differences were not found in a comparable group of girls (Mond, Stich, Hay, Krämer, & Baune, 2007). In sum there is no consistency among the various studies which leads to the need in further research.

The purpose of the current study was to examine the association between physical fitness and overweight among children with DCD in Israel, and to compare children with and without DCD with respect to physical fitness and overweight. Given the inconsistencies found in previous studies with respect to gender differences, comparisons of these variables also will be examined between the boys and girls in the study sample.

2. Method

2.1. Study design and sampling

The design of this study is comparative and correlational, using convenience sampling. Participants were recruited from a children’s developmental treatment center and a children’s workout facility, both of which are located in a children’s rehabilitation hospital in central Israel. Others were recruited by referrals.

DCD was determined by: (a) total scores at or below the 16th percentile on the movement assessment battery for children 2 (MABC-2; Henderson, Sugden, & Barnett, 2007); (b) reports of parents in the Demographic, Medical and Motor Questionnaire (Cermak, 2007), and the determination that a child’s motor skill deficits interfered with at least two functions in school (e.g., writing, playing, participating in gym) and/or activities of daily living (ADL; e.g., dressing, grooming, recreation at home or school). Children were excluded from the study if they had a chronic illness that may have affected their appetite and food intake (i.e., heart disease, cancer, thyroid disorder, cystic fibrosis, and/or gastrointestinal disease); if
they had a developmental disability other than DCD; or if they regularly received a medication that may affect their activity level, growth or appetite (e.g., steroids or stimulants).

2.2. Participants

The study sample included 69 children between the ages of 6–11 years. All of the children studied in regular education elementary schools. The sample comprised two groups: (a) children with DCD ($n = 22$; $M$ age = 8.70 [SD = 1.36], 16 boys [73%] and 6 girls [27%]); and (b) typically developing (TD) children ($n = 47$; $M$ age = 8.90 [SD = 1.52], 34 boys [72%] and 13 girls [28%]).

2.3. Measures

2.3.1. DCD diagnosis

2.3.1.1. Movement assessment battery for children–2 (MABC-2; Henderson et al., 2007). The MABC-2 is a norm-referenced, valid and reliable performance test. It was designed to evaluate gross and fine motor functioning and assess motor impairment in children aged 3:0–16:11 years, as well as to screen and identify children with DCD (Missiuna, Rivard, & Bartlett, 2006). The instrument is used worldwide to assess motor coordination abilities and has been used to identify DCD in many studies.

2.3.1.2. Demographic, Medical and Motor Questionnaire (Cermak, 2007). This is a parent-report questionnaire, developed with the purpose of collecting demographic information (e.g., age, gender, country of origin, parental education, etc.), the child’s medical history and current status, and information about the child’s motor coordination skills, as well as his/her past and present daily life abilities, as reflected in 24 functional activities. The questionnaire was translated into Hebrew and adjusted for Israeli children.

Inclusion in the DCD group was comprised of the MABC-2 the total score equal to or less than the 16th percentile, and the parents’ report that the child’s deficits in motor skills interfered with at least two functions daily life activities.

2.3.2. Instruments

2.3.2.1. BMI and body fat percentage. Anthropometric measures (height and weight) were obtained for each participant. Each child’s height was measured with a Wall Mounted Stadiometer (SECA, Germany) calibrated to 0.1 cm, and weight/percent body fat was measured with a Tanita digital scale (Tanita Corp., Tokyo, Japan). Body mass index (BMI) was calculated from measures of height and weight using age- and gender-specific growth charts (CDC; National Center for Health Statistics [NCHS], n.d.) for children ages 2–20, and LMS parameters needed to generate percentile and z-scores. z-Scores were used because the sample included male and female participants ranging from 6 through 11 years, and research with children has shown that BMI varies as a function of the child’s age and gender (CDC, 2013). A BMI $z$-score of 1.04 was used as an indicator of at-risk-for-overweight (85th percentile) and 1.65 as an indicator of overweight (95th percentile).

2.3.2.2. Strength subtest of the Bruininks–Oseretsky test of motor proficiency – second edition (BOT-2) (Bruininks & Bruininks, 2005). The BOT-2 is a norm-referenced test that assesses gross and fine motor coordination in children ages 4–21 years. The strength subtest includes five items that assess gross motor strength through muscular endurance tasks such as push-ups, sit-ups, and standing broad-jump. Scores for subtests are reported in standard scores ($M = 15$, SD $= 5$). Reliability and validity are provided in the manual (Bruininks & Bruininks, 2005) and several subsequent test reviews have examined its psychometric properties (Wuang and Su, 2009; Deitz et al., 2007).

2.3.2.3. Six-minute walk test (6MWT). This test requires the child to walk as rapidly as possible for six continuous minutes in a 30-m long hallway (American Thoracic Society, 2002). It is widely used as an outcome measure in cardiopulmonary rehabilitation to assess physical capacity and has been used as a measure in over 1400 published research articles (PubMed review, April 2013). Although the majority of research has been with adults, several studies have been conducted with healthy children in the UK (deGroot and Takken, 2011), Austria (Geiger et al., 2007), China (Li et al., 2005, 2007) and in the U.S. (Roush et al., 2006) have used it with children with moderate–severe disabilities. A practice walk was conducted. In order to interpret the 6MWT and understand the range of factors that may influence the fitness of children with DCD, we also assessed heart rate with a Polar monitor while the child performed the 6MWT.

2.3.2.4. Heart rate (HR). The heart rate was assessed before, during, and after the 6MWT using a Polar monitor (Polar®, Finland) with an elastic chest strap and sensor attached. This monitor stores information on HR during the test period and was downloaded on to a computer for analysis. We measured pre-exercise heart rate, average heart rate during exercise, percent of time in the target zone (60–80% of maximum heart rate), and post-exercise heart rate immediately following the test and at 1 and 2 min post-walking. Heart rate may be considered a proxy measure of the effort exerted. (Freedson and Miller 2000) suggested that monitoring simultaneous heart rate with motion may facilitate examinations of responses to physical activity.
2.4. Procedure

Following ethical approval of the Helsinki Committee for Human Rights, children were recruited to the study. One member of the research team conducted initial phone screening interviews to determine if the child could participate in the study and what is expected from the child and parents. The assessment battery was administered in a quiet, bright and spacious room by four other qualified pediatric occupational therapists trained in administering the battery; inter-rater reliability had been established among them. They collected the data and were blind as to group composition (with or without DCD). In the first session a written consent from both parents and child was obtained and the parents filled out the questionnaires as the child underwent the MABC-2 test. Next the child’s weight was measured using the Tanita and height was measured using a stadiometer. BMI was calculated using height and weight. A practice 2-minute walk test, including heart rate monitoring, was administered to familiarize the child with these assessments. In a second session, the strength subtest of the BOT-2 was performed, followed by the six-minute walk test (6MWT) with a Polar monitor to measure heart rate.

2.5. Statistical analysis

Data analysis was done using SPSS for Windows version 20. Descriptive statistics and comparisons of the two groups (i.e., DCD and TD) and between gender (boys and girls within the groups) were done using t-tests. In order to study the interaction effect of group and gender a 2-way ANOVA was further conducted. Within the DCD group Pearson correlations were calculated between the variables and the significant results are presented as graphs with the $R^2$ level of variance explained. The significance level of all the statistical analyses was set at 0.05.

3. Results

Means and standard deviation with t-test analyses between DCD and TD children were performed to compare measures of weight, body fat percentage and BMI, physical fitness on the 6MWT and strength on the BOT-2. For all the above variables significant differences were found between the diagnostic groups with the TD group performing better ($t = 2.35–2.60$, $p < .05$) and for the BOT-2 ($t = 5.65$, $p < .000$) (see Table 1).

Means and standard deviations for subgroups according to gender (girls and boys) in each group were calculated (see Table 2). In all comparisons the means were higher for the DCD group within each gender. Additionally, within the DCD group a significant difference was found between girls and boys for percent body fat ($t = 2.36$, $p < .028$); such that it was lower among the boys and approached significance in the same direction for BMI ($t = 1.89$, $p < .074$).

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Children with DCD (n = 22)</th>
<th>Typical children (n = 47)</th>
<th>t-Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>34.64 ± 9.90</td>
<td>29.10 ± 7.11</td>
<td>2.35**</td>
</tr>
<tr>
<td>Percentage body fat</td>
<td>22.66 ± 9.20</td>
<td>17.09 ± 5.79</td>
<td>2.60**</td>
</tr>
<tr>
<td>BMI</td>
<td>19.13 ± 3.93</td>
<td>16.86 ± 2.15</td>
<td>2.54**</td>
</tr>
<tr>
<td>Total distance on the 6MWT</td>
<td>0.53 ± 0.08</td>
<td>0.60 ± 0.11</td>
<td>2.52**</td>
</tr>
<tr>
<td>Strength subtest, BOT-2</td>
<td>10.23 ± 3.01</td>
<td>15.38 ± 3.75</td>
<td>5.65***</td>
</tr>
</tbody>
</table>

Note: DCD, developmental coordination disorder; BMI, body mass index; 6MWT, six-minute walking test; BOT-2, Bruininks–Oseretsky test of motor proficiency – 2nd edition.

** $p < .05$.

*** $p < .000$.

Table 2

<table>
<thead>
<tr>
<th>Group</th>
<th>Variable</th>
<th>DCD (n = 22) 16 boys: 6 girls</th>
<th>Typical (n = 47) 34 boys: 13 girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>Weight</td>
<td>32.79 ± 9.034</td>
<td>29.52 ± 7.99</td>
</tr>
<tr>
<td></td>
<td>% Fat</td>
<td>20.08 ± 8.63</td>
<td>17.60 ± 5.03</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td>18.21 ± 3.50</td>
<td>16.86 ± 2.38</td>
</tr>
<tr>
<td>Girls</td>
<td>Weight</td>
<td>39.56 ± 11.27</td>
<td>28.01 ± 4.01</td>
</tr>
<tr>
<td></td>
<td>% Fat</td>
<td>29.52 ± 7.39</td>
<td>15.75 ± 7.58</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td>21.56 ± 4.23</td>
<td>16.85 ± 1.42</td>
</tr>
</tbody>
</table>

Note: DCD, developmental coordination disorder; BMI, body mass index; % fat, percentage body fat.
### Table 3
Two-way ANOVA by group (DCD and typically developing children) and by gender.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>654.480</td>
<td>1</td>
<td>654.480</td>
<td>10.22</td>
<td>.002</td>
</tr>
<tr>
<td>Gender</td>
<td>82.905</td>
<td>1</td>
<td>82.905</td>
<td>1.29</td>
<td>.259</td>
</tr>
<tr>
<td>Group * gender</td>
<td>204.562</td>
<td>1</td>
<td>204.562</td>
<td>3.19</td>
<td>.079</td>
</tr>
<tr>
<td><strong>% Fat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>786.209</td>
<td>1</td>
<td>786.209</td>
<td>17.63</td>
<td>.000</td>
</tr>
<tr>
<td>Gender</td>
<td>171.541</td>
<td>1</td>
<td>171.541</td>
<td>3.85</td>
<td>.054</td>
</tr>
<tr>
<td>Group * gender</td>
<td>379.552</td>
<td>1</td>
<td>379.552</td>
<td>8.51</td>
<td>.005</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>109.469</td>
<td>1</td>
<td>109.469</td>
<td>14.62</td>
<td>.000</td>
</tr>
<tr>
<td>Gender</td>
<td>31.420</td>
<td>1</td>
<td>31.420</td>
<td>4.43</td>
<td>.039</td>
</tr>
<tr>
<td>Group * gender</td>
<td>33.689</td>
<td>1</td>
<td>33.689</td>
<td>4.50</td>
<td>.038</td>
</tr>
<tr>
<td><strong>Total distance 6MWT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>0.060</td>
<td>1</td>
<td>0.060</td>
<td>5.91</td>
<td>.018</td>
</tr>
<tr>
<td>Gender</td>
<td>0.000</td>
<td>1</td>
<td>0.000</td>
<td>0.01</td>
<td>.916</td>
</tr>
<tr>
<td>Group * gender</td>
<td>0.002</td>
<td>1</td>
<td>0.002</td>
<td>0.18</td>
<td>.671</td>
</tr>
<tr>
<td><strong>BOT-2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>307.691</td>
<td>1</td>
<td>307.691</td>
<td>24.00</td>
<td>.000</td>
</tr>
<tr>
<td>Gender</td>
<td>0.764</td>
<td>1</td>
<td>0.764</td>
<td>0.06</td>
<td>.808</td>
</tr>
<tr>
<td>Group * gender</td>
<td>0.344</td>
<td>1</td>
<td>0.344</td>
<td>0.03</td>
<td>.870</td>
</tr>
</tbody>
</table>

**Note:** DCD, developmental coordination disorder; BMI, body mass index; % fat, percentage body fat; 6MWT, six-minute walking test; BOT-2, Bruininks-Oseretsky test of motor proficiency – 2nd edition.

*p < .05.

***p < .000.

Bold values are statistically significant at *p < .05. and ***p < .000.

![Graph 1](image1.png)

**Fig. 1.** Distribution of weight and BMI with heart rate in the DCD group during the 6MWT. Note: kg, kilograms; BMI, body mass index; DCD, developmental coordination disorder; 6MWT, six-minute walking test.
In order to further explore the relationships between diagnostic groups and gender, a 2-way analysis of variance was performed (see Table 3). For all comparisons significant main effects were found between diagnostic groups where the TD had better scores. Significant main effects for gender were found for BMI (BMI, $F = 4.43, p < .039$) within the DCD group. A significant interaction effect was found for fat percentage ($F = 8.51, p < .005$) and BMI ($F = 4.50, p < .038$).

The distribution of weight and BMI with heart rate during the 6MWT was analyzed among the DCD group participants and the results are presented in Fig. 1. These indicate that as weight and BMI increase, heart rate increases as well (weight, $R^2 = .358$; BMI, $R^2 = .276$). Fig. 2 shows the same relationship for distance walked on the 6MWT and BMI, such that children with a higher BMI walked a shorter distance (BMI $R^2 = .233$).

4. Discussion

In recent years researchers have demonstrated a growing interest in the consequences of DCD on children’s health. Special attention has been focused on factors that underlie children’s physical health such as physical fitness and overweight/obesity. The purpose of the study was to examine the association between physical fitness and overweight in a sample of Israeli children in comparison to typical children, and to examine gender differences.

The current findings on Israeli children are consistent with most of the literature and add to the results of previous studies, in which a significant difference was found between typical children and children with DCD in physical fitness (Burns et al., 2009; Cairney et al., 2007; Silman et al., 2011; Wu et al., 2010). Furthermore, similar results have been reported regarding weight (Beutum et al., 2013; Cairney et al., 2010; Fong et al., 2011; Zhu et al., 2011), suggesting that the profile of physical fitness and weight in children with DCD is a worldwide phenomenon.

The relationships between weight and BMI with heart rate during the 6MWT and the total distance walked suggests that overweight may have implications with respect to physical fitness as the variance explained was between $R^2 = 0.23$ and 0.35 (see Figs. 1 and 2). Overweight has been reported to be a major concern for all children, but of an even greater concern for children with disabilities in whom obesity rates were 38% higher than for children without disabilities (CDC, 2014; Rimmer, Rowland, & Yamaki, 2007). The influence of overweight and obesity on physical fitness has also been demonstrated among children with attention deficit hyperactive disorder (ADHD) (Braet et al., 2007) and learning disabilities (LD) (Bandini, Curtin, Hamad, Tybor, & Must, 2005).

Moreover, gender differences between boys and girls with DCD have demonstrated that girls weigh more, and have a significantly greater percent of body fat than boys. However, this group comprised only six girls so the generalizability of these findings requires the employment of a larger sample size. Results of most other studies with children with DCD did not examine gender, and those that did, reported inconsistent findings demonstrating that the distribution of overweight within gender was different in these populations. In the current study, girls with DCD were more overweight than boys. In contrast, some studies examining the ADHD population showed that boys were more overweight, as well as more hyperactive and impulsive compared to typically developing children, but these findings were not found among girls (Braet et al., 2007). These inconsistent findings in the literature regarding gender obesity among children with DCD, warrant further investigation. Furthermore, the relationship between physical fitness and obesity and its implications requires further study. It is even more important as the risks related to obesity increases with age (Cairney et al., 2010).

The main limitation of the study is its small sample size and especially the size of the DCD group, thus results should be considered with caution in the subgroups according to gender. However, in spite of the small sample size the comparison between gender and the interactions were highly significant especially for the DCD group suggesting that girls with DCD may be at greater risk for overweight.
5. Conclusion

The current study highlights the findings that children with DCD have lower physical fitness and are overweight compared to typical children. It is essential to study the relationships between overweight, physical fitness and gender in order to increase participation in physical activities in children with DCD as well as with other disabilities.

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