

The impact of obesity on developmental coordination disorder in adolescence

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ABSTRACT

Developmental coordination disorder (DCD) as well as overweight and obesity are of increasing importance in the study of human development. Data on the relation between DCD and obesity in adolescence are of particular interest because both phenomena are unlikely to disappear with age. The objective of this study was to determine the impact of obesity on severe DCD in adolescence. A total of 99 obese adolescents aged between 11 and 16 years and 99 normal weight controls matched for age and gender were included in this cross sectional study. The Movement Assessment Battery for Children 2 (age band 3) was used to determine subjects' stage of motor development. Results made clear that (i) obese show a higher severe DCD risk in comparison to normal weight adolescents ($p < .01$) which is (ii) most pronounced in balance ($p < .01$), and (iii) thereby rather appears in boys ($p \leq .10$). Thus, our results at least do not exclude the possibility that obesity might have a detrimental effect on the etiopathology of DCD beyond childhood. Therefore, primary obesity prevention measures may additionally contribute to the prevention of a possible consolidation of severe DCD.

Keywords:

Developmental coordination disorder
Obesity
Adolescence

1. Introduction

1.1. Relevance, concepts and key assumptions

Developmental coordination disorder (DCD) as well as overweight and obesity are of increasing importance in the study of human development mainly because both conditions are associated with a number of comorbidities (Schelbert, 2009; Visser, 2003) and rising prevalence rates that differ between cultures (Tsiotra et al., 2006; [WHO], 2007).

Following the diagnostic criteria provided in the Diagnostic and Statistic Manual of Mental Disorders (DSM IV TR; American Psychiatric Association [APA], 2000) DCD is most likely present when "Performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence" (APA, 2000). Furthermore, it is important to note that "The disturbance is not due to a general medical condition [...]" and

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does not meet criteria for a pervasive developmental disorder" (APA, 2000). Overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health (WHO, 2011).

When discussing the relation between DCD and overweight/obesity two key assumptions should be considered. On one hand, it has been suggested that DCD or low motor proficiency, respectively, could lead to a lack of physical activity (PA; Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006; for the mediating role of generalized self efficacy regarding PA see Cairney et al., 2005) which may increase the risk for being overweight or obese (key assumption a; for the mediating role of PA in the relation between DCD and body fat see Faight, Hay, Cairney, & Flouris, 2005).

However, if we consider DCD as well as overweight and obesity as parts of a dynamic and reciprocally structured system (Hands & Larkin, 2002) it is also feasible, that overweight and obesity could lead to a lack of PA (for PA differences between normal weight and overweight see Deforche, De Bourdeaudhuij, D'Hondt, & Cardon, 2009a) which may negatively influence the etiopathology of DCD beyond childhood (key assumption b).

1.2. Empirical evidence and research desiderata

The relation of DCD and body composition has received much attention in the literature (see the review by Rivilis et al., 2011). While two out of three recently published longitudinal studies (Cairney et al., 2010; Osika & Montgomery, 2008; in contrast Hands, 2008) provide some empirical evidence supporting key assumption (a), longitudinal data supporting key assumption (b) are lacking. Results of recent cross sectional studies at least indicate that:

- (i) the general motor skill level in obese is lower than that in normal weight and overweight children (e.g. Zhu, Wu, & Cairney, 2011),
- (ii) these differences are particularly pronounced for (static and dynamic) balance (BL; D'Hondt, Deforche, De Bourdeaudhuij, & Lenoir, 2009; Zhu et al., 2011; in depth Graf et al., 2004), followed by ball skills (here: aiming and catching, AC; D'Hondt et al., 2009; in contrast Zhu et al., 2011) and finally fine motor skills (here: manual dexterity, MD; D'Hondt et al., 2009; in contrast Zhu et al., 2011; in depth under different postural constraints D'Hondt, Deforche, De Bourdeaudhuij, & Lenoir, 2008), and
- (iii) these differences in balance are more pronounced in boys than in girls (Mond, Stich, Hay, Kraemer, & Baune, 2007; partially Cawley & Spiess, 2008; in contrast Zhu et al., 2011; in depth for boys Deforche et al., 2009b; Goulding, Jones, Taylor, Piggot, & Taylor, 2003).

However, besides the lack of longitudinal evidence, current research on key assumption (b) appears fragmentary as most of the studies cited under (i) (iii) refer to childhood whereas data in adolescence are lacking to a large extent. However, these data would be particularly relevant because children with a (severe) DCD diagnosis are unlikely to outgrow these deficits during adolescence (e.g. Cantell, Smyth, & Ahonen, 2003) and the increasing prevalence of childhood overweight and obesity presumably persists as children grow older (WHO, 2007).

1.3. Study aim, research question and hypotheses

The aim of this study was to determine the impact of overweight/obesity on DCD in adolescence. From a clinical perspective and in accordance with the current literature (Cantell et al., 2003), we particularly focused on the distinction between typically developing adolescents (TD) and those with a severe DCD (SDCD) diagnosis in order to facilitate identifying risk groups with proven needs. In statistical terms (maximization of primary variance; Kerlinger & Lee, 2000) the distinction between normal weight and obese adolescents promised the highest explanatory power. Therefore, we specifically questioned the impact of obesity on SDCD in adolescence and hypothesized that:

- (i) There is an impact of obesity on SDCD in adolescence because we expect obese to show a higher SDCD risk in comparison to normal weight adolescents.
- (ii) The level of impact of obesity on SDCD in adolescence is task specific because we expect the higher SDCD risk of obese in comparison to normal weight adolescents to be most pronounced in balance (BL) followed by aiming and catching (AC) and finally manual dexterity (MD).
- (iii) The level of impact of obesity on BL SDCD in adolescence is gender specific because we expect the higher BL SDCD risk of obese in comparison to normal weight adolescents to be more pronounced in boys than in girls.

2. Materials and methods

2.1. Sample and clinical obesity criteria

A total of 99 obese adolescents (Diagnosis by ICD 10 E66; 66.8; 66.9, WHO, 1993; BMI >97th percentile, Kromeyer Hauschild et al., 2010) in clinical treatment (Clinical Intervention Group, CIG: mean age = 14.04, SD = 1.29 [11;00 16;00];

Table 1
Anthropometric characteristics of the CIG.^a

Measurement		Total	Boys	Girls
BMI ^b [kg/m ²]	Mean	33.33	33.56	33.09
	SD	3.71	3.84	3.60
	Min	25.15	25.93	25.15
	Max	41.87	41.87	40.46
	N	78	40	38
Height [m]	Mean	1.66	1.68	1.64
	SD	0.08	0.09	0.05
	Min	1.50	1.50	1.53
	Max	1.83	1.83	1.75
	N	79	41	38
Mass [kg]	Mean	92.13	94.83	89.28
	SD	13.47	15.31	10.68
	Min	62.00	67.00	62.00
	Max	129.00	129.00	105.00
	N	80	41	39

^a Clinical intervention group.

^b Body mass index.

boys: $N = 52$, mean age = 13.79, $SD = 1.33$ [11.00 16.00]; girls: $N = 47$, mean age = 14.32, $SD = 1.20$ [11.00 16.00]) and 99 normal weight control subjects (Control Group, CG) matched for age and gender¹ were originally included in this cross sectional study. At the time of data collection, 17 CIG subjects fell below the 97th BMI percentile and were therefore excluded from further considerations. Table 1 shows the final anthropometric characteristics of the CIG.

2.2. DCD Diagnosis

The Movement Assessment Battery for Children 2 (age band 3; Henderson, Sugden, & Barnett, 2007) respectively its German language adaptation (Petermann, 2009) was used to determine the stage of motor development in both groups. Measurements for eight subtests assigned to the three dimensions manual dexterity (MD), aiming and catching (AC) and balance (BL) were recorded and summed to a total impairment score (TIS). Participants were classified as TD ($PR > 15$), border line DCD ($PR 6 - 15$) or SDCD ($PR \leq 5$).

2.3. Data analysis

After elimination of borderline cases and pairwise deletion of missing data,² a minimum of 156 complete data sets remained (TIS: $N = 156$, CIG: $N = 64$, CG $N = 92$; MD: $N = 165$, CIG: $N = 71$, CG: $N = 94$; AC: $N = 170$, CIG: $N = 77$, CG: $N = 93$; BL: $N = 165$, CIG: $N = 71$, CG: $N = 94$).

Logistic regression was used to test the directional hypotheses (one sided testing). Weight status (normal weight as reference category, obesity) was used to predict the change in DCD risk from TD to SDCD. Because of the large age range, chronological age was included as a control variable in all statistical tests. In addition, the assumption of gender specific influences (hypothesis iii) necessitated the inclusion of gender in the tests addressing hypothesis (i) and (ii). Gender specific influences of obesity on BL SDCD were tested by considering the dummy coded group \times gender interaction. The significance level for all statistical tests was set a priori to $\alpha = .050$. All statistical tests were carried out in SPSS 19 (IBM, New York, USA).

3. Results

3.1. Descriptive measures

Descriptive measures (see Table 2) showed (i) a higher prevalence of obese (CIG; 28.1%) with TIS SDCD in comparison to their normal weight controls (CG; 3.3%), (ii) a comparatively high prevalence of MD SDCD (26.8%) in obese, which can be explained by a disproportionately low prevalence of obese boys with AC SDCD (11.9%) and (iii) a disproportionately low prevalence of obese girls with BL SDCD (21.2%).

3.2. Hypothesis testing

Logistic regressions (Tables 3–7) showed that (i) controlled for age and gender, obese participants had a 11.74 higher SDCD risk in comparison to normal weight adolescents (Table 3), (ii) controlled for age and gender, the higher SDCD risk for

¹ Matching method was chosen because an active manipulation of weight-status was not possible.

² Pairwise deletion was considered appropriate because the proportion of missing item responses for each scale only ranged from 0.6 to 5.5% and the overall percentage of missing data was 1.93% (21 out of 1.186).

Table 2
Prevalence of SDCD among obese and normal-weight boys and girls.

	Total		Boys		Girls	
	CG ^a	CIG ^b	CG ^a	CIG ^b	CG ^a	CIG ^b
	% (N)	% (N)	% (N)	% (N)	% (N)	% (N)
TIS ^c	3.3 (92)	28.1 (64)	2.0 (51)	25.7 (35)	4.9 (41)	31.0 (29)
MD ^d	7.4 (94)	26.8 (71)	8.5 (47)	25.6 (39)	6.4 (47)	28.1 (32)
AC ^e	6.5 (93)	19.5 (77)	3.8 (52)	11.9 (42)	9.8 (41)	28.6 (35)
BL ^f	5.3 (94)	26.8 (71)	2.0 (49)	31.6 (38)	8.9 (45)	21.2 (33)

^a Control group (normal-weight).

^b Clinical intervention group (obese).

^c Total impairment score.

^d Manual dexterity.

^e Aiming and catching.

^f Balance.

Table 3
Logistic regression to determine the impact of obesity on TIS-SDCD^a (N = 156).

Predictor	B	Wald-Chi ²	df	p ^b	OR
Group (CIG ^c)	2.46	14.30	1	.000	11.74
Age	-0.05	0.05	1	.416	0.96
Gender (girls)	0.41	0.62	1	.216	1.51
Intercept	-2.97	1.00	1	.158	0.05

-2 Log-likelihood = 101.87; Nagelkerkes R² = .235.

^a Total impairment score – severe developmental coordination disorder.

^b p-Value (one-sided testing).

^c Clinical intervention group.

Table 4
Logistic regression to determine the impact of obesity on MD-SDCD^a (N = 165).

Predictor	B	Wald-Chi ²	df	p ^b	OR
Group (CIG ^c)	1.51	10.00	1	.001	4.51
Age	0.08	0.18	1	.337	1.08
Gender (girls)	-0.07	0.02	1	.443	0.94
Intercept	-3.60	1.87	1	.086	0.03

-2 Log-likelihood = 132.13; Nagelkerkes R² = .117.

^a Manual dexterity – severe developmental coordination disorder.

^b p-Value (one-sided testing).

^c Clinical intervention group.

Table 5
Logistic regression to determine the impact of obesity on AC-SDCD^a (N = 170).

Predictor	B	Wald-Chi ²	df	p ^b	OR
Group (CIG ^c)	1.28	6.07	1	.007	3.58
Age	-0.06	0.09	1	.380	0.94
Gender (girls)	1.10	4.40	1	.018	3.01
Intercept	-2.40	0.70	1	.201	0.09

-2 Log-likelihood = 115.63; Nagelkerkes R² = .124.

^a Aiming and catching – severe developmental coordination disorder.

^b p-Value (one-sided testing).

^c Clinical intervention group.

Table 6
Logistic regression to determine the impact of obesity on BL-SDCD^a (N = 165).

Predictor	B	Wald-Chi ²	df	p ^b	OR
Group (CIG ^c)	1.87	12.34	1	.000	6.49
Age	0.08	0.18	1	.334	1.08
Gender (girls)	-0.10	0.04	1	.421	0.91
Intercept	-3.96	2.25	1	.067	0.02

-2 Log-likelihood = 121.36; Nagelkerkes R² = .159.

^a Balance – severe developmental coordination disorder.

^b p-Value (one-sided testing).

^c Clinical intervention group.

Table 7Logistic regression to determine the gender-specific impact of obesity on BL-SDCD^a ($N = 165$).

Predictor	<i>B</i>	Wald-Chi ²	df	<i>p</i> ^b	OR
Group (CIG ^c)	3.10	8.38	1	.002	22.09
Age	0.08	0.17	1	.340	1.08
Gender (girls)	1.50	1.71	1	.096	4.46
Group × gender	-2.08	2.71	1	.050	0.13
Intercept	-4.95	3.10	1	.039	0.01

-2 Log-likelihood = 118.09; Nagelkerkes $R^2 = .191$.^a Balance – severe developmental coordination disorder.^b *p*-Value (one-sided testing).^c Clinical intervention group.

obese subjects in comparison to normal weight adolescents was most pronounced in balance (BL: OR = 6.49; Table 6) followed by manual dexterity (MD: OR = 4.51; Table 4) and aiming and catching (AC: OR = 3.58; Table 5), and (iii) controlled for age and at tendency, the higher BL SDCD risk of obese was slightly more pronounced in boys (group × gender interaction: $p = .050$; Table 7).

4. Discussion

4.1. Progress of knowledge, summary and explanations

This study provides novel data because it is one among few studies explicitly focusing on the impact of obesity on severe DCD in adolescence.

The results of this study indicate that (i) there is an impact of obesity on TIS SDCD in adolescence because obese subjects showed a higher TIS SDCD risk in comparison to their normal weight controls, (ii) the level of impact (of obesity on SDCD in adolescence) is task specific because the higher BL SDCD risk of obese in comparison to their normal weight controls was most pronounced in balance followed by manual dexterity and aiming and catching, and (iii) the impact of obesity on BL SDCD may depend on gender because the higher SDCD risk of obese in comparison to their normal weight controls was slightly more pronounced in boys.

Since (task and gender specific) significant differences in the prevalence of SDCD between normal weight and obese are still identifiable in adolescence, our results at least do not exclude the possibility that obesity might have a detrimental effect on the etiopathology of SDCD beyond childhood (key assumption b). Therefore, the results of this study may be explained as follows. Hypothesis (i): Obese are generally assumed to have a unique set of physiological, biomechanical, and neuromuscular barriers to PA and thus are more susceptible to a more sedentary lifestyle in comparison to their normal weight peers (Shultz, Deforche, Byrne, & Hills, 2011). Resulting reduced opportunities to experience and challenge their own body could therefore make obese more susceptible to consolidate an already existing SDCD in comparison to their normal weight SDCD peers. Hypothesis (ii): An active lifestyle is usually accompanied by a variety of different locomotive activities such as running, jumping, and climbing, and one of the main prerequisite for these activities is healthy postural control (Haywood & Getchell, 2005). An obesity induced shift towards a less active lifestyle presumably leads to a lack of locomotion and therefore to a lack of situations that train and challenge postural control. This pathway represents one possibly explanation for the comparatively high BL SDCD risk in obese. However, aiming and catching tasks also rely on postural balance control, and hence we would have expected a larger impact in comparison to MD SDCD in this regard.

Hypothesis (iii): The higher BL SDCD risk in obese boys may simply reflect the observation that girls are generally more skilled in static and dynamic balance tasks (Mickle et al., 2011; Wagner, Worth, Schlenker, & Bös, 2010).

4.2. Implications, limitations and recommendations/challenges

If the explanations provided above hold true, task and gender specific intervention strategies (in overview Polatajko & Cantin, 2005) should be combined with primary obesity prevention measures (in overview Connelly, Duaso, & Butler, 2007) at an early stage to prevent a possible consolidation of SDCD beyond childhood.

However, our considerations are based on cross sectional data that do not provide final empirical evidence on the causal relationship. In addition, the current study did not include any measurement of PA, and hence the assumption of a mediated impact remains hypothetical. Besides the unanswered questions of directionality and mediation one may question the use of M ABC 2 as it has not been established as the gold standard in diagnosing DCD, yet (Venetsanou et al., 2011). However, recent work at least proves factorial validity of M ABC 2 for age band 1 (Ellinoudis et al., 2011) and 2 (Wagner, Kastner, Petermann, & Bös, 2011) as well as its clinical relevance (Kastner, Mayer, Walther, & Petermann, 2010; Kastner, Petermann, & Petermann, 2010). Finally, BMI may not be a sufficiently sensitive measure for determining obesity (Rivilis et al., 2011; in contrast Willett, Jiang, Lenart, Spiegelman, & Willett, 2006).

Therefore, future investigations should implement extreme group comparisons into longitudinal designs including the concept of PA with a simultaneous use of additional DCD (Brown & Lalor, 2009) and alternative body composition (Rivilis et al., 2011) measurements.

5. Conclusion

Our results suggest that obesity could be detrimental for a (task and gender specific) consolidation of severe DCD beyond childhood because corresponding differences between normal weight and obese subjects are still present in adolescence. However, because of the cross sectional design of this study and the limited validity of measurements, final empirical evidence is still lacking.

Conflict of interest statement

The authors declare that there is no actual or potential conflict of interest.

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