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Excessive body weight in developmental coordination disorder: A systematic review and meta-analysis

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ABSTRACT

Evidence on the link between developmental coordination disorder (DCD) and obesity and overweight is mixed. Based on a pre-registered protocol (PROSPERO: CRD42023429432), we conducted the first systematic review/meta-analysis on the association between DCD and excessive weight. Web of Science, PubMed and an institutional database aggregator were searched until the 18th of December 2023. We assessed study quality using the Newcastle-Ottawa Scale and study heterogeneity using Q and I2 statistics. Data from 22 studies were combined, comprising 11,330 individuals out of which 1861 had DCD. The main analysis showed a significant association between DCD and higher body weight (OR:1.87, 95 % CI =1.43, 2.44). Meta-regression analyses indicated that the relationship was mediated by age, with stronger effects in studies with higher mean age (p 0.004). We conclude that DCD is associated with obesity and overweight, and this association increases with age. Our study could help to implement targeted prevention and intervention measures.

1. Introduction

Developmental coordination disorder (DCD) is a neurodevelopmental condition characterized by persistent difficulties in motor coordination and control that significantly impede daily activities and academic achievements fied in childhood. A range of prevalences between 2 % and 8 % in school-age children is typically reported (American Psychiatric Association, 2022). While the specific cause remains unclear, the challenges posed by DCD extend beyond the physical realm, affecting psychosocial well-being and often persisting into adulthood (Hellgren et al., 1993; Rasmussen and Gillberg, 2000; Zaguri-Vittenberg et al., 2023). Research has shown that learning difficulties, language difficulties and/or ADHD often co-occur with DCD (Dewey et al., 2002; Kadesjö and Gillberg, 2001; Wilson et al., 2001).

In recent years, research has increasingly pointed to the intricate connections between physical and mental health, emphasizing the importance of understanding the interplay between various conditions. One of the physical disorders that has been most consistently associated in both register-based primary studies or meta-analyses to developmental disorders has been excessive body weight (Cortese et al., 2008;

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Hanć and Cortese, 2018). Indeed, a 2022 umbrella review on the association between mental and physical disorders combining evidence from 45 meta-analyses showed that obesity had a significant transdiagnostic association with multiple mental disorders in children and adolescents, including ADHD, ASD, and depression (Arrondo et al., 2022). However, that umbrella review did not identify any meta-analysis linking DCD and physical disorders in the literature.

The World Health Organization (WHO) (2000) defines overweight and obesity as the "abnormal or excessive accumulation of fat that may be harmful to health". WHO uses percentiles based on the Body Mass Index (BMI) to classify and assess weight in children and adolescents. BMI is a measure that relates a person's weight to their height, and it is calculated by dividing a person's weight in kilograms by the square of their height in meters. BMI-for-age percentiles help determine where an individual falls in comparison to others of the same age and sex. Those between the 85th and 95th percentile are considered to be overweight, whereas those above the 95th percentile are considered obese. We will use the encompassing term "excessive weight" whenever we refer to both obesity and overweight.

Excessive body weight during childhood and adolescence has been associated with an increased risk of obesity in adulthood and the diagnosis of chronic diseases such as diabetes, hypertension, and cardiovascular conditions (Hales et al., 2020; The World Health Organization (WHO), 2000)

With regards to DCD, several studies have shown that motor difficulties associated with this condition are related to low levels of physical activity and higher levels of sedentary behavior (Caçola, 2016; Cairney and Veldhuizen, 2013; Cavalcante Neto et al., 2020; Howie et al., 2016; Tan et al., 2022) The persistent failures and limitations in performing free or structured activities that require motor skills could lead individuals with DCD to spend less time engaging in these activities or avoid them altogether (Biotteau et al., 2016; Caçola, 2016; Cairney, 2015; Cairney and Veldhuizen, 2013; Rivilis et al., 2011), especially if they involve group activities (Cairney, 2015). This may lead to their motor skills not developing as expected for the chronological age, a general lack of physical fitness (Caçola, 2016; Cairney, 2015; Cairney and Veldhuizen, 2013), and, over time, to excessive body weight. Alternatively, both DCD and overweight/obesity may share common risk factors, such as genetic predisposition and environmental influences, that could lead to an early onset of the association. While there are few or no studies directly aiming to investigate these potential common factors in the case of DCD, such a relationship has been explored in the case of ADHD, with a study revealing that familial risk factors common to attention-deficit/hyperactivity disorder (ADHD) and overweight/obesity extend beyond those specifically leading to overweight/obesity through the mediation of ADHD (Chen et al., 2017).

While there is some preliminary evidence directly linking DCD and excessive body weight, results to date have been inconsistent (Hendrix et al., 2014). Moreover, to the best of our knowledge, there has not been a quantitative synthesis of the existing data aiming to quantify the magnitude of the possible association and the factors moderating it. Gaining insight into the link between DCD and excessive body weight, and/or other physical disorders, could allow for early intervention strategies. Indeed, identifying and addressing coordination difficulties in childhood may help in developing targeted interventions to promote physical activity and prevent the development of obesity in the long term. More specifically, schools play a crucial role in addressing the needs of children with DCD. Hence, understanding the relationship with obesity could inform the development of educational interventions that support physical activity and healthy habits within the school environment. The current study aims to statistically summarize the existing evidence on the association between excessive body weight and developmental coordination disorder.

2. Methods

We followed the 2020 PRISMA guidelines (Page et al., 2021), and pre-registered the protocol in PROSPERO (CRD42023429432).

2.1. Search strategy

Three major databases were searched: PubMed (Medline Plus), Web of Science core database and UNIKA, an institutional reference aggregator (*UNIKA*: http://www.unav.edu/en/web/biblioteca), that uses the EBSCO discovery service (http://support.ebsco.com/help/ index.php?lang=en&int=eds) to provide a list of references combining both internal (library) and external (data- base vendors) sources. Searches were first carried out on November 5th, 2022, and updated on December 18th, 2023. No time, type of document, or language restriction was implemented. For PubMed-Medline Plus, the search was not limited to any field. For Unika and Web of Science, the search was limited to titles and abstracts through the website options due to database limitations on the number of possible keywords in a string when searching in all fields in the case of WoS, and the ratio between number of results and finally included papers seen in our pilot phase in the case of Unika. Initially the search draw on that of larger project aimed at exploring the relationships between DCD and any physical condition was used for all databases (Arrondo et al., 2022). Given the paucity of studies on association between DCD and physical conditions other than overweight/obesity, we limited the scope of the study focusing on the relationship between DCD and excessive body weight. Additional details, including search syntax, can be found in Supplementary tables S1 and S2.

Database searches were complemented through the following methods: 1-evaluation of bibliographic sections of included studies and systematic reviews of interest; 2-inverse search for articles citing a previous systematic review on the topic (Hendrix et al., 2014); 3-publication records of key authors on the field.

2.2. Eligibility

We included studies (typically cross-sectional or prospective) that provided data on the strength of the association between DCD and physical disorders in children. We included studies that either quantified the association through effect sizes (Typically odds ratios-ORs-), or provided data for their calculation. Additionally, studies reporting the physical disorder as a continuous variable for those with and without DCD (e.g., Body Mass Index -BMI- instead of obesity) were also included.

Inclusion criteria for DCD were as follows: 1) a categorical classification of DCD according to DSM (third and following editions) and ICD (ninth and following editions); 2) a diagnosis based on the standardized MABC (Henderson et al., 2012), BOT (Bruininks and Bruininks, 2005) or BOT- short test; 3) a positive response to the question: "Did your doctor ever tell you that you have DCD?" or similar; 4) a diagnosis of DCD recorded in medical files/registries. We included studies where individuals with and without DCD approximately represented the general population of typically developing individuals or individuals with DCD. i.e., they were not selected to take part in the study due to having an additional disorder. A typical case of exclusion would be a study selecting only a sample of individuals with ADHD in which DCD and weight were measured. However, cases and controls selected in a clinical setting were allowed.

2.3. Selection and data collection processes

Screening and full text evaluation was carried out independently by two authors in Covidence (*Covidence Systematic Review Software*, n.d.) and articles were moved to the following phase through consensus. Whenever consensus could not be reached, the two senior authors (GA and SM) decided on a given record or study. After this stage, it was clear that there were few studies on disorders other than excessive body

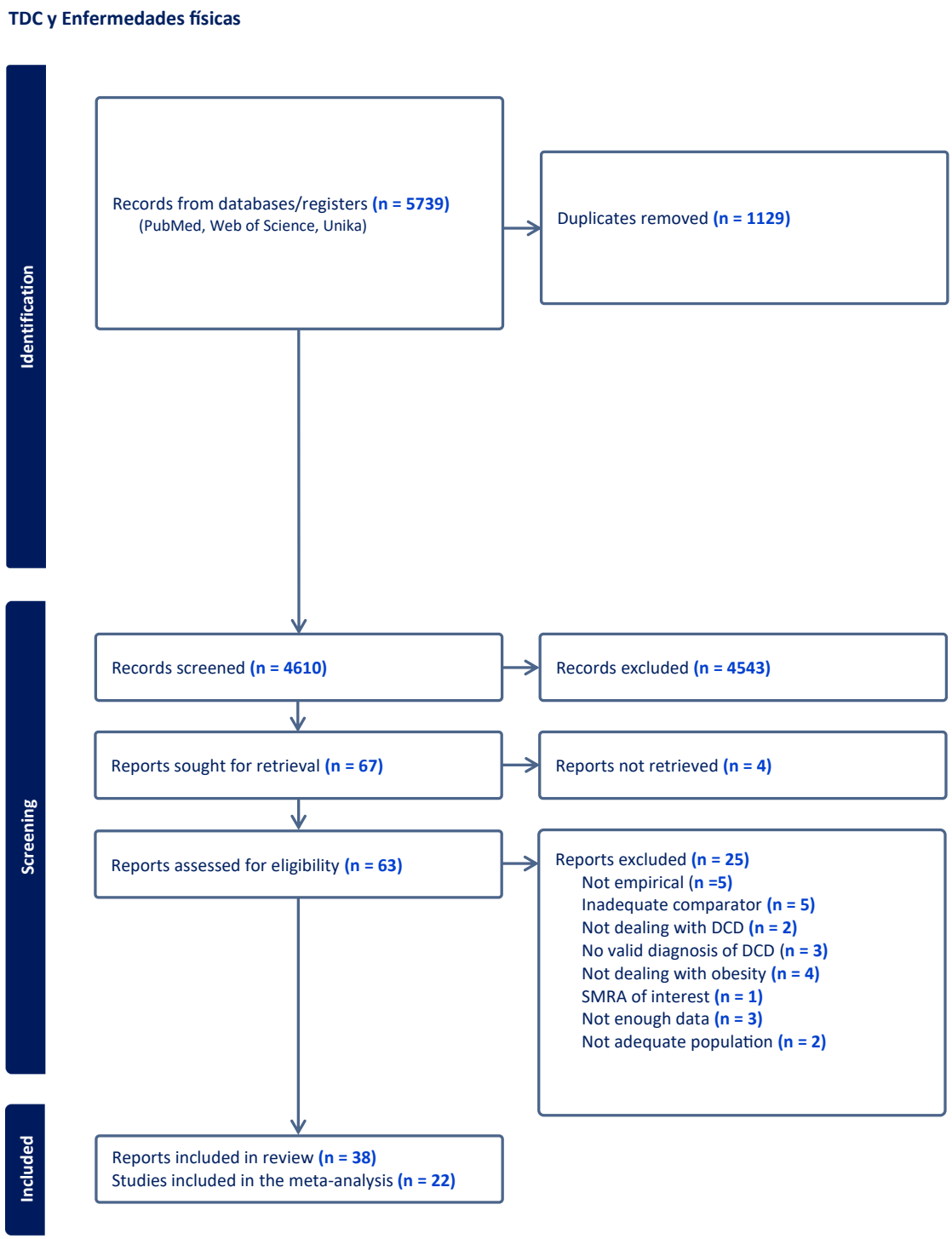

Fig. 1. PRISMA 2020 flow chart- selection of studies.

Table 1
Characteristics of the included studies. CS: cross-sectional, L: longitudinal. NOS: Total number of stars in the Newcastle-Ottawa scale. PHAST: Physical Health and Activity Study Team, NW-CHILD: North-West Child Health Integrated with Learning and Development, CATCH: Coordination and Activity Tracking in Children study. Unselected sample: a cross-sectional study in which both DCD and BMI are evaluated in a sample. Selection based on DCD: studies in which a group of individuals with DCD is recruited and a control group is recruited afterwards. Selection based on excessive body weight: studies in which a group of individuals with excessive body weight is recruited and and group of individuals without excessive body weight is selected afterwards.

Author year	Country	Database	Temporality	Design	Setting	Diagnosis of DCD Tool	N	Mean Age	SD Age	Gender (% Females)	NOS
Bell, (2003)	South Africa		CS	Unselected sample	Community-based	MABC	346	10.98	0.83	100	6
Cairney 2005	Canada	PHAST	CS	Unselected sample	Community-based	MABC	590	11.46	1.45	45.42	6
Cairney 2010	Canada		L	Unselected sample	Community-based	BOT-Short test	2278	9.9	0.5	49.2	6
Capistrano 2015	Brazil		CS	Unselected sample	Community-based	MABC	83	8.9	0.74	50.6	4
Cermak 2015	USA		CS	Selection based on DCD	Community-based	MABC	75	NR	1.45	33.33	1
Denysschen 2021	South Africa	NW-CHILD	CS	Unselected sample	Community-based	MABC	146	10.05	0.41	50	5
dos Santos 2015	Brazil		CS	Unselected sample	Community-based	MABC	581	8.35	NR	48.88	7
Du 2020	China		CS	Unselected sample	Community-based	MABC	2185	5.95	2.27	47.69	7
Farhat 2015	Tunisia		CS	Selection based on DCD	Community-based	MABC	37	NR	NR	NR	4
King-Dowling 2018	Canada	CATCH	CS	Unselected sample	Community-based	MABC	589	NR	NR	42.6	6
Li 2011	Taiwan		L	Selection based on DCD	Community-based	MABC	50	9	0	56	5
Li 2023	Taiwan		CS	Unselected sample	Community-based	MABC	825	8.33	NR	48	4
Lifshitz 2014	Israel		CS	Unselected sample	Hospital-based	MABC	69	NR	NR	27.54	4
Miranda 2011	Brazil		CS	Unselected sample	Community-based	MABC	380	8.5	1.1	52.11	7
Psotta 2009	Czech Republic		CS	Unselected sample	Community-based	MABC	422	12.8	1.1	48.1	6
Schott 2007	Germany		CS	Unselected sample	Community-based	MABC	261	7.77	1.89	45.21	7
Tsiotra 2009	Greece		CS	Unselected sample	Community-based	BOT-Short test	177	NR	NR	45.19	3
Valentini 2023	Brazil		CS	Unselected sample	Community-based	MABC	352	7.5	1.5	47.2	6
Wagner 2011	Germany		CS	Selection based on excessive weight	Hospital-based	MABC	198	14.04	1.29	47.47	5
Wu 2010	Taiwan		CS	Unselected sample	Community-based	MABC	41	NR	NR	53.66	5
Yam 2022	Hong Kong		CS	Unselected sample	Community-based	MABC	121	NR	NR	30.58	5
Zhu 2011	Taiwan		CS	Unselected sample	Community-based	MABC	2029	NR	NR	46.87	7

weight, hence limiting our inclusion criteria solely to this domain.

The following data were extracted from each study in a pre-defined excel sheet by two of the authors in the data extraction phase: 1-bibliographic details, 2-geographic origin of data, 3-design and setting, 4-operational definition of DCD and excessive body weight, 5-description of the overall, DCD, non-DCD, obesity and non-obese groups, 6-numerical data on outcomes. When including studies with multiple longitudinal data points, the first data point was extracted. Studies were similarly likely to use the 95th or 85th percentile (pc) to define excessive body weight and DCD. Hence, we decided to extract results for both types of classifications. In the present article, we use the terms obesity for the pc 95 and overweight for the pc 85. Conversely, we will refer to probable DCD (pDCD) for the pc 95 while we will leave borderline DCD (bDCD) for the pc 85. Risk of bias of the included studies was evaluated using a modified version of the Newcastle-Ottawa scale (NOS) for case-control studies (Wells et al., 2000), which can be found in Table S3.

2.4. Data synthesis

Numerical data from all studies were transformed into ORs either through their direct calculation (for those cases in which both DCD and excessive weight were treated as dichotomous variables) or by first calculating Cohens d and then approximating it to an odds ratio assuming that the continuous data followed the logistic distribution (for those cases in which mean BMI was provided for the DCD and non-DCD group) (Borenstein et al., 2009). Then, we used meta-analytical techniques to pool the data for two groups of controls and obtain an average BMI in the non-DCD group in one of the included studies (Schott et al., 2007). Stata 18 (StataCorp, 2023) was then used to carry out all meta-analytical analyses, based on random-effect models using the restricted maximum likelihood (REML) method to estimate the heterogeneity variance. The key analysis pooled any definition of DCD or excessive body weight (i.e., either pc 95 % or 85 for both), prioritizing the most stringent one whenever a study provided data on multiple thresholds. Heterogeneity was assessed using tau and I squared. I^2 represents the proportion of total variation in study estimates that is due to heterogeneity rather than chance. It is expressed as a percentage, where higher values indicate greater heterogeneity. Values above 50 % are considered to indicate substantial heterogeneity, and above 75 % high heterogeneity. Tau is an estimate of the standard deviation of true effect

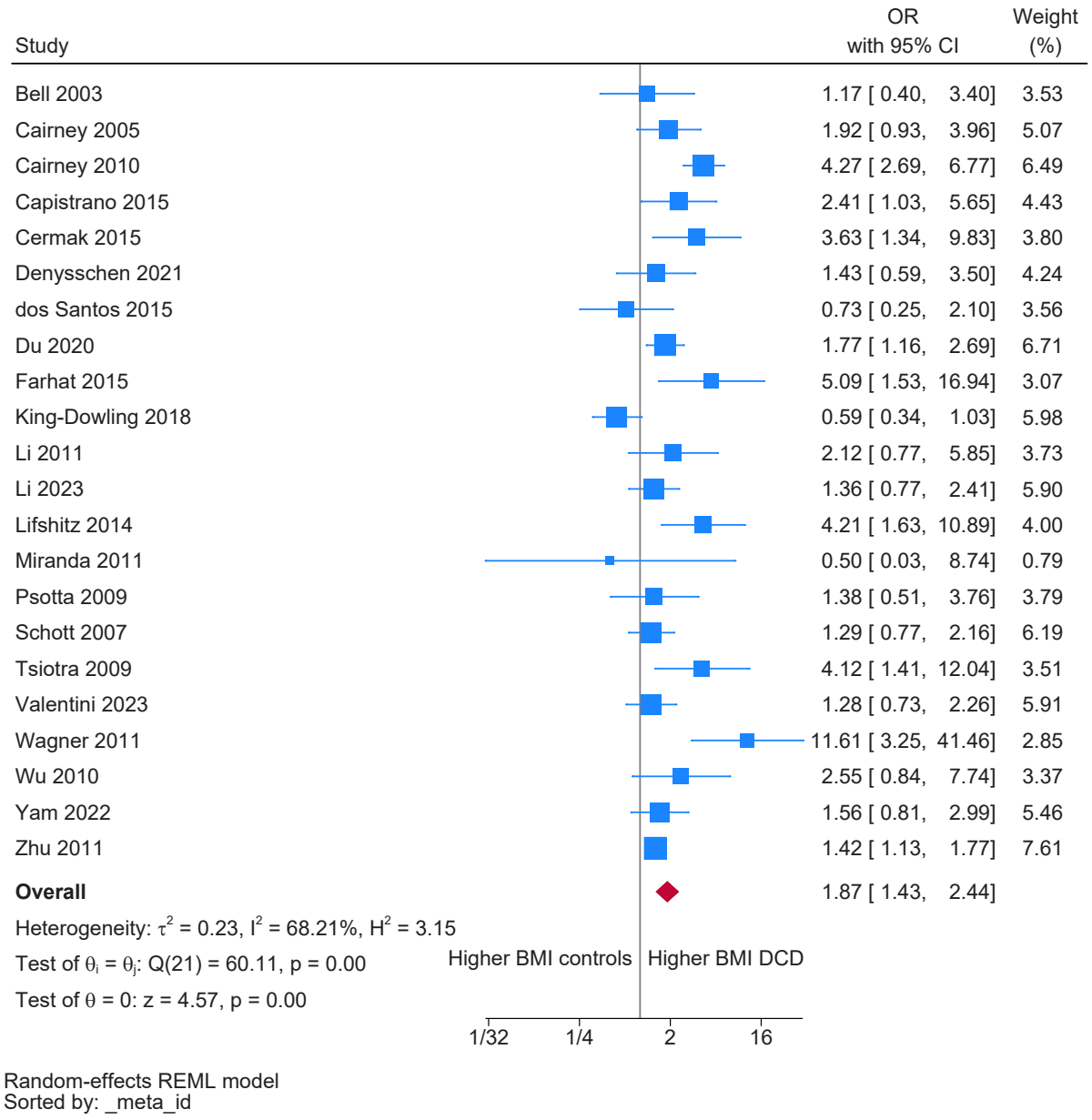

Fig. 2. Forest plot. Risk of higher weight and DCD.

sizes across studies. It quantifies the extent of variation among the effects beyond what is expected by chance. A higher tau indicates more variability among the study effects. Funnel plots and Egger tests were implemented to evaluate small-sample bias. A leave-one-out strategy was used to explore the influence of specific studies. We used meta-regression to independently test for the effect of age, percentage of females in the overall and DCD groups, overall sample size and risk of bias whenever at least 10 studies were available for a predictor. Sensitivity analyses were carried out with alternative definitions of DCD and excessive body weight (pDCD-obesity, bDCD-obesity, pDCD-overweight, bDCD- overweight), excluding ORs derived from transforming continuous data, limiting studies to community studies or those that used

Table 2
Summary of statistical analyses- Meta-analyses. k: the number of studies included, OR: odds ratio, LBCI and UBCI: lower and upper bound of the confidence interval for the odds ratio, pDCD: probable DCD (i.e. >pc95), bDCD: borderline DCD (i.e. >pc85).

Description	k	OR	LBCI	UBCI	tau^2	I^2 (%)	H^2
Main analysis	22	1.867	1.428	2.44	0.2318	68.21	3.15
Untransformed ORs	14	1.647	1.148	2.361	0.3025	76.79	4.31
Unselected samples	18	1.635	1.258	2.126	0.1735	64.75	2.84
Community samples	19	1.644	1.276	2.117	0.1616	62.09	2.64
pDCD&Obesity	5	1.564	0.799	3.06	0.4	84.12	6.3
bDCD&Obesity	7	1.296	1.081	1.555	0	0	1
pDCD&Overweight	8	1.36	0.915	2.022	0.2453	82.45	5.7
bDCD&Overweight	10	1.221	1.071	1.391	0	0	1

unselected samples (i.e., that did not select a DCD or excessive body weight group and then looked for controls). We were not able to carry out additional pre-planned analyses such as comparing cross-sectional vs longitudinal studies, or studies on children vs adults due to paucity of relevant studies for these analyses.

3. Results

3.1. Study selection

The flow chart of the screening process is depicted in Fig. 1. We retained 22 studies for the meta-analysis (Bell, 2003; Cairney et al., 2005, 2010; Capistrano et al., 2015; Cermak et al., 2015; Denysschen et al., 2021; Dos Santos et al., 2015; Du et al., 2020; Farhat et al., 2015; King-Dowling et al., 2018; Lifshitz et al., 2014; Li et al., 2011, 2023; Miranda et al., 2010; Psotta and Jakub, 2009; Schott et al., 2007; Tsiotra et al., 2009; Valentini et al., 2023; Wagner et al., 2011; Wu et al., 2010; Yam et al., 2022; Zhu et al., 2011) Non-retrievable reports and reasons for exclusion of studies that went into the second stage can be found in Table S4 and S5. Initial reviewers´ agreement in the screening phase as measured by Coheńs Kappa was 0.40 (95 % CI 0.32–0.5), increasing to 0.55 (95 % CI 0.33–0.77) for the full-text evaluation. There were several instances of multiple reports of the same study (See Table S6). In those cases, we used data from the most relevant reference for our study as the key reference and complemented it with additional information derived from the other references if needed. Importantly, two studies that provided implausible BMI statistics but otherwise fulfilled our inclusion criteria (Nobre et al., 2023; Zanella et al., 2018) were found. The authors of these two studies were contacted without response. We used another report (Valentini et al., 2023) of the same study in one case (Nobre et al., 2023), while we were unable to include the other study (Zanella et al., 2018) due to concerns around reliability of data that we could not verify with the authors. Additional details on the issues found with these two reports can be found in Table S7. Hence, we finally included 22 studies in our review.

3.2. Study characteristics

The main study characteristics are reported in Table 1. Table S8 provides additional information on the cases and controls in each study. Retained studies had been published in English and spanned two decades (2003–2023). The three most frequent countries where they had been carried out were Brazil (n=4), Taiwan (n=4) and Canada (n=3). Two studies had a longitudinal design (Cairney et al., 2010; Li et al., 2011), whereas the remaining were cross-sectional. Most studies were based on community (n=17) or hospital (n=1) samples that were evaluated both for DCD and weight, whereas three studies (Cermak et al., 2015; King-Dowling et al., 2018; Li et al., 2011) recruited a sample of individuals with DCD and typically developing controls for them, and one selected a sample of children with overweight and normal-weight controls (Wagner et al., 2011). All the studies used standardized batteries to identify DCD: 19 used the MABC and 3 the BOT short test. Regarding the threshold used for identification, half the studies used the 95 % percentile and the other half the 85 % percentile (or roughly equivalent cut-offs). Conversely, nine studies reported obesity statistics, four reported on overweight and eight reported BMI as a continuous measure.

The mean age range between studies went from six to fourteen years (median=9 years). The total sample size for the main analysis combined 11,330 individuals (median=304, range 37–2091), out of which 1861 had DCD. While most studies had a similar number of males and females among their participants, the number of males was greater among the DCD group (median=75 %, range= 27.7 %-78.26 %). Data on ethnicity or socioeconomic status was sparse among studies. None of the studies had adjusted ORs that could be pooled. Statistical data obtained from each study is shown in Table S9 (BMI as a dichotomous variable) and Table S10 (BMI as a continuous variable).

The scores on the Newcastle-Ottawa Scale showed that, overall, studies had a low risk of bias (range 1–7, median 5 out of 7 possible stars), A summary of the risk of bias across studies is included in Table 1, whereas the rating for each study and item can be found in Table S11.

3.3. Data synthesis

The key summary effect (k=22) indicated a significant association between excessive body weight and DCD (OR= 1.87, 95 % CI =1.43, 2.44), albeit characterized by substantial heterogeneity (Q=60.11, p< 0.001, I^2: 68.21 %) (Fig. 2) but no evidence of publication bias (Figure S1). This effect was not drastically changed by the removal of specific studies (Figure S2). Importantly, meta-regression analyses indicated that our results were mediated by age (p=0.004), with greater ORs in studies with higher average age. Percentage of females (overall p=0.43; in the DCD group p=0.86) or study size (p=0.65) were not shown to influence the pooled effect. Results were similar when analyses were limited to studies with ORs derived solely from BMI as a dichotomous variable (OR= 1.65, 95 % CI =1.15, 2.36), community samples (OR= 1.63, 95 % CI =1.26, 2.13), or unselected samples (OR= 1.87, 95 % CI =1.43, 2.44). When combining studies with specific definitions of DCD and high BMI (pDCD-obesity, bDCD-obesity, pDCD-overweight, bDCD- overweight) effect sizes were in a similar range, albeit they were only significant when using the less stringent threshold of DCD. A summary of all statistical analyses can be found in Tables 2 and 3 and Figures S3 to S9.

4. Discussion

To the best of our knowledge, this is the first meta-analysis of studies providing data on the association between DCD and obesity/overweight, exploring the magnitude of this relationship and the factors that modify it.

Our findings suggest an increased risk of obesity/overweight in individuals with DCD. This result complements previous similar studies on other developmental disorders such as ADHD (Cortese et al., 2008; Hanć and Cortese, 2018) and ASD (Cortese et al., 2022) and points towards weight being a physical correlate that is closely linked to mental health (Arrondo et al., 2022). All the included studies except two (Cairney et al., 2010; Li et al., 2011) had a cross-sectional design. Moreover, they had all been carried out in children or adolescents. A consequence of this is that it is complicated to infer directionality in the association over time. While DCD could be leading to higher weight, the opposite could also be true. Indeed, it is reasonable to think that individuals with excessive body weight would also perform worse in DCD batteries as these batteries typically measure fine and gross motor abilities. Nevertheless, the results of our meta-regression analysis show that the risk for obesity increases with age in those with DCD as compared to typically developing individuals. This gives some leverage to DCD causing the increase in weight rather than the other way around. We are not aware of any evidence supporting that overweight leads individuals to get poorer results in movement batteries the older children get. However, if we consider DCD as an early trait of an individual, it is plausible that its influence accumulates over time, leading to a higher risk of overweight and obesity in older children. Our results are in overall agreement with those of the longitudinal studies found in our search. Li et al. (Li et al., 2011) is a small study with similar differences across groups at the different timepoints. However, the study by Cairney et al. (Cairney et al., 2010) is the biggest among the included ones and had a lower risk of bias. While, per protocol, we only included data from the first time point to avoid data non-independence issues, its results indicated that differences between individuals with DCD and typically developing individuals tended to increase

Further well-designed longitudinal studies could enhance our understanding of this relationship across the developmental span.

Table 3
Summary of statistical analyses- Meta-regression. LBCI and UBCI: lower and upper bound of the confidence interval in a meta-regression analysis predicting DCD and each variable separately. Coeff is the coefficients of the model. Std err is the standard error.

	Values for variable of interest						Values for constant					
Variable	Coeff.	Std err	z	P>|z|	LBCI	UBCI	Coeff.	Std err	z	P>|z|	LBCI	UBCI
Overall sample size	-0.00009	0.0002	-0.45	0.655	-0.00049	0.00031	0.716	0.202	3.54	0	0.319	1.112
% females overall	-0.00890	0.0114	-0.78	0.435	-0.03123	0.01344	1.014	0.558	1.82	0.069	-0.079	2.108
% females in DCD	0.00147	0.0081	0.18	0.856	-0.01440	0.01735	0.404	0.357	1.13	0.259	-0.297	1.104
Mean age	0.16877	0.0590	2.86	0.004	0.05313	0.28442	-0.899	0.538	-1.67	0.095	-1.953	0.156

Moreover, future studies should try to clarify whether the association between weight and DCD also holds in adulthood.

When analyzing the outcomes of this study, it is essential to consider its strengths and limitations. Among the positive aspects are the presence of a pre-registered protocol, reducing the potential for reporting bias, and the incorporation of grey literature. Regarding limitations, it is noteworthy that three of the included studies were closely related as they had been carried out by the same study team and had a similar design (Cairney et al., 2010, 2005; King-Dowling et al., 2018). This limits to some extent the generalization of our results. Another limitation is that due to the paucity of data for certain outcomes, we could not assess moderating factors in the association between DCD and being overweight. For example, ethnicity and socio-economic status were rarely reported, while both have been found to greatly influence weight status (Kim et al., 2024; Min et al., 2021), and to a lesser extent, motor ability (Kakebeeke et al., 2021; Morrison et al., 2018). Additional studies should aim to disentangle factors driving the heterogeneity of our results. Also, most studies identified cases solely through the use of a threshold in a standardized movement battery such as the BOT or MABC, instead of a full clinical diagnosis. In this regard, our results might be better considered as applying to individuals "at risk for DCD" (Tamplain and Cairney, 2024). Of note, this is a typical feature of many meta-analyses, as they try to attain a balance between including few and small studies with strict clinical criteria or more and bigger studies that are more representative of the overall population. Moreover, we were able to show that changing the threshold for the identification of DCD did not impact the results greatly. Finally, while most studies had a low risk of bias, 17 of the 22 studies had issues with comparability between cases and controls. This raises the possibility that there are differences between groups that are influencing the results found.

Overall, our results have relevant implications from both a research and clinical perspective. In terms of research, there is a growing interest in the relationship between mental and physical disorders, and our meta-analysis is an additional piece of the puzzle on a frequently overlooked disorder. The association of DCD with an increased risk of excessive body weight also has important clinical implications in terms of prevention. In fact, as we demonstrated that children with DCD are an "at risk" population for obesity and overweight, prevention is pivotal to tackle this problem. Our findings emphasize the need for healthcare professionals, including pediatricians, rehabilitation specialists and allied health professionals, to recognise recognize and address the complex interplay between DCD and the increased susceptibility to excessive weight. Understanding this relationship can inform targeted interventions, therapeutic strategies and multidisciplinary approaches aimed at both the management of DCD and the prevention or alleviation of weight-related problems in affected individuals.

Beyond the clinical setting, the public health implications of our study are far-reaching. Being overweight in childhood is strongly associated with a range of health problems that can persist into adulthood, including cardiovascular disease, diabetes, and mental health problems (Arrondo et al., 2022). By delineating the relationship between DCD and excessive weight, our findings contribute valuable insights to the broader public health discourse. This knowledge can inform preventive measures, health promotion campaigns and policy initiatives focused on early identification, intervention, and support for children with DCD, thereby mitigating the long-term health consequences associated with being overweight.

In summary, the study of the relationship between DCD and obesity is relevant not only for individual health outcomes, but also for the development of targeted interventions, public health strategies and a comprehensive understanding of the factors influencing the well-being of individuals with developmental coordination difficulties.

5. Conclusion

Our comprehensive meta-analysis the highest available level of evidence supporting with DCD have a significantly elevated risk of excessive body weight compared to those without DCD. The implications of these findings reverberate not only within the realms of clinical practice but also hold profound significance for public health initiatives.

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CRediT authorship contribution statement

Conceptualization: L.G, S.C, G.A and S.M; methodology: L.G, S.C, G.A and S.M; formal analysis: G.A.; investigation: L.G., P.L., D.R., U.P, C.G, G.A, S.M; resources: G.A.; writing—original draft preparation: L.G. and G.A.; writing—review and editing: L.G., S.C., P.L., D.R., U.P, C.G, G.A, S.M; supervision: G.A., S.M.; project administration: G.A. S.M; funding acquisition: Not Applicable. All authors have read and agreed to the published version of the manuscript.

Declaration of Conflict of Interest

The authors declare no conflict of interest.

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Institutional review board statement

Not applicable.

Informed consent statement

Not applicable.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.neubiorev.2024.105806.

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