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Deficits in Physical Activity Behaviour in Children with Developmental Coordination Disorder: Systematic Review

Déficits en el Comportamiento de Actividad Física en Niños con Trastorno del Desarrollo de la Coordinación: Revisión Sistemática

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Abstract: The Developmental Coordination Disorder (DCD) affects about 5 to 6% of school-aged children, being one of the most common developmental problems in childhood. A dated review identified that DCD children had lower levels of physical activity than their peers however, they did not investigate the implications of this lower activity in the children's lives. The present systematic review aimed to identify: i) differences in physical activity levels between children with developmental coordination disorder (pDCD) and typical development, ii) the repercussions of these differences, and iii) main instruments used in the measurement of physical activity. A comprehensive search in five databases was performed (Science Direct, PubMed, Web of Science, EBSCO, Cochrane), including grey literature. After finding 785 publications, 16 studies were included. This review verified that pDCD children have lower levels of moderate and vigorous physical activity, with possible implications at physical (e.g., higher percentages of fat mass) and psychological (e.g., increased levels of frustration) levels. This review confirms that children with pDCD are less active than children with typical development and have a higher risk of developing cardio-metabolic diseases. Parents, teachers, schools and communities should create motivational environments for youngsters with DCD to engage and maintain physical activity as they move into adulthood.
Key Words: children, DCD, physical activity, health.

Resumen: El Trastorno del Desarrollo de la Coordinación (DCD) afecta alrededor del 5 al 6% de los niños en edad escolar, siendo uno de los problemas de desarrollo más comunes en la infancia. Una revisión fechada identificó que los niños DCD tenían niveles más bajos de actividad física que sus compañeros; sin embargo, no investigaron las implicaciones de esta menor actividad en la vida de los niños. La presente revisión sistemática tuvo como objetivo identificar: i) diferencias en los niveles de actividad física entre niños con trastorno del desarrollo de la coordinación (pDCD) y desarrollo típico, ii) las repercusiones de estas diferencias, y iii) principales instrumentos utilizados en la medición de la actividad física. Se realizó una búsqueda exhaustiva en cinco bases de datos (Science Direct, PubMed, Web of Science, EBSCO, Cochrane), incluida la literatura gris. Después de encontrar 785 publicaciones, se incluyeron 16 estudios. Esta revisión verificó que los niños con pDCD tienen menores niveles de actividad física moderada y vigorosa, con posibles implicaciones a nivel físico (p. ej., mayores porcentajes de masa grasa) y psicológico (p. ej., mayores niveles de frustración). Esta revisión confirma que los niños con pDCD son menos activos que los niños con desarrollo típico y tienen mayor riesgo de desarrollar enfermedades cardiometabólicas. Es crucial desarrollar para promover mejores estrategias para aumentar la actividad física en estos niños.
Palabras clave: niños, DCD, actividad física, salud.

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Introduction

The Developmental Coordination Disorder (DCD) affects about 5 to 6% of school-aged children Vaivre-Douret (2014), thus being one of the most common developmental problems in childhood (Harrowell, Hollén, Lingam, & Emond, 2018; Zwicker, Missiuna, Harris, & Boyd, 2012). This problem has a higher prevalence in male children (Villa De Gregorio, Ruiz Pérez, & Barriopedro Moro, 2019; Zwicker et al., 2012) and is characterized by difficulties in fine and gross motor coordination (Harrowell et al., 2018), postural control (Geuze, 2005), spatial-temporal organization (Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013), concentration and attention, and eye movements (Rafique & Northway, 2015), negatively affecting children's day-to-day activities, including physical activity, school success, physical and psychological health (Aertssen, Bonney, Ferguson, & Smits-Engelsman, 2018; Sit, Yu, Wong, Capio, & Masters, 2019). When comparing children with typical motor development and children with probable DCD, it can be seen that DCD's take longer to perform tasks involving motor coordination (Aertssen et al., 2018) and that their participation in leisure and/or physically intense activities is substantially lower than children with typical motor development (Sit et al., 2019; Zwicker et al., 2012).

Due to the coordination difficulties experienced by children with probable DCD, physical activity may not be comfortable, stimulating or pleasurable for them (Aertssen et al., 2018; Sit et al., 2019). However, the lower practice of physical activity by these children brings with it several physical, metabolic and even psychological health problems. Low aerobic and anaerobic capacity, low level of strength production, a higher body mass index (BMI) and a higher risk of obesity (associated with diabetes or cardiovascular disease) are some of the comorbidities present in children with DCD (Aertssen et al., 2018; Sit et al., 2019). On the other hand, when physical activity is promoted in children with DCD, it shows long-term positive effects on their health status, including decreased anxiety, improved physical fitness and motor coordination

(Aertssen et al., 2018). In this sense, promoting physical activity for these children is especially important, in order to break or prevent the cycle of negative effects caused by a sedentary life. Unfortunately, this disorder is chronic, DCD does not simply disappear as time goes by (Cousins & Smyth, 2003). Being that the negative cycle of inactivity can be maintained and worsened in adult life. While, on the other hand, an early diagnosis accompanied by an early intervention may help to decrease the negative effects of DCD and provide a better quality of life for these children, and later, in their adult life (Camden, Wilson, Kirby, Sugden, & Missiuna, 2015).

The level of physical activity in children with DCD has been widely studied in recent years, rendering it necessary to review the written material for a better understanding of the physical activity behaviour in children with DCD, i.e., the frequency of physical activity and whether they practice it formally or informally. Rivilis and collaborators (Rivilis et al., 2011) presented the last systematic review that included the topic of physical activity levels in children with DCD. The authors compared both physical activity and fitness in children with DCD and their typically developing peers, also exploring the influence between these variables. The authors identified lower levels of physical activity in children with DCD, however, they did not investigate the implications of this lower activity in these children's lives, nor did they address the instruments used to carry out this assessment. Therefore, a literature review addressing the levels of physical activity in children with DCD and, simultaneously, the consequences of the levels of physical activity behaviour, becomes relevant to verify whether this negative trend continues and, if so, to consider measures to reverse it.

This review aims to: i) verify the differences of physical activity behaviour between the children with DCD and typical developing children; ii) if any, verify the repercussions of these differences on physical activity behaviour; and, iii) identify which instruments are used to measure physical activity in this issue.

Method

Although the topic of physical activity in children with DCD has been addressed in a previous systematic review (Rivilis et al., 2011), the authors focused their data collection and discussion on the relationship between physical activity and the physical condition of these children, so they did not investigate its implications in their lives or the assessment instruments used (specific objectives of this present review). In this sense, the present review presents its own protocol, defined according to its specific objectives, not replicating the protocol of the previous review.

Protocol and Eligibility criteria

The protocol followed for this review is based on the PRISMA guidelines (Moher et al., 2015). The research question was developed according to the PICOS protocol, and the following parameters were defined for each point: (P) - children (aged between 3 and 18 years) diagnosed, pre-diagnosed or at risk of DCD; (I) - possible, but not necessary, intervention aiming at improving physical activity levels in children with DCD; (C) - comparison between physical activity levels of children with DCD and those with typical motor development; (O) – physical activity levels; (S) - cross-sectional or longitudinal studies.

The research question was thus defined as "Are the physical activity levels of children with DCD similar to the physical activity levels of children with typical development?".

The following inclusion criteria were defined: i) all children enrolled in the studies have to be diagnosed or pre-diagnosed with DCD or at risk of DCD, through at least one validated instrument (MABC or BOT); ii) children must be aged between 3-18, which coincides with the age range validated by the instruments; iii) children's physical activity levels have to be measured through validated instruments, e. g. written tests (validated questionnaires) and/or practical tests (accelerometer, pedometer or other validated instrument for measuring physical activity); iv) studies must include comparison of physical activity between groups (Rivilis et al., 2011).

To complete the diagnosis of DCD, there are several criteria that must be ensured, namely medical and psychological observation, to ensure the absence of other physical or psychological problems that justify coordination difficulties (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012). When the battery test is applied in isolation, we can only say that these children are possible or probable DCD (pDCD). Considering that many of the studies do not include medical and psychological assessment, we chose to also include participants with pDCD, as long as they were screened by a gold standard (MABC or BOT), ensuring the accuracy of the screening. In the presentation of results by study, Table 1, information about the diagnosis despite of DCD is presented.

Search Strategy and Databases

Databases with a broad spectrum of areas that study DCD were selected for the search: PubMed, ScienceDirect, Web of Science, EBSCO and Cochrane. In the field of grey literature, the following databases were used: Google Scholar, ProQuest dissertations and theses, and Greylit. Considering the existence of a previous systematic review dating from 2011 in which the topic of physical activity in children with DCD was addressed, only studies from that date were considered (Rivilis et al., 2011), until May 13, 2020. No language restriction was defined.

The following keywords were used in this search: ((developmental coordination disorder) OR (dyspraxia) OR (DCD)) AND ((children) OR (child) OR (young person) OR (adolescent)) AND (physical activity)).

Study Selection

The study selection was performed with the Zotero reference management software. All relevant articles were entered into the software and duplicates were removed. Two independent reviewers screened the titles, abstracts and full articles according to the eligibility criteria. Disagreements were resolved through discussion between the two reviewers, and when necessary, with the help of a third reviewer (e.g., Mercê, Pereira, Branco, Catela, & Cordovil, 2021). The flowchart illustrating the selection process is presented in Figure 1.

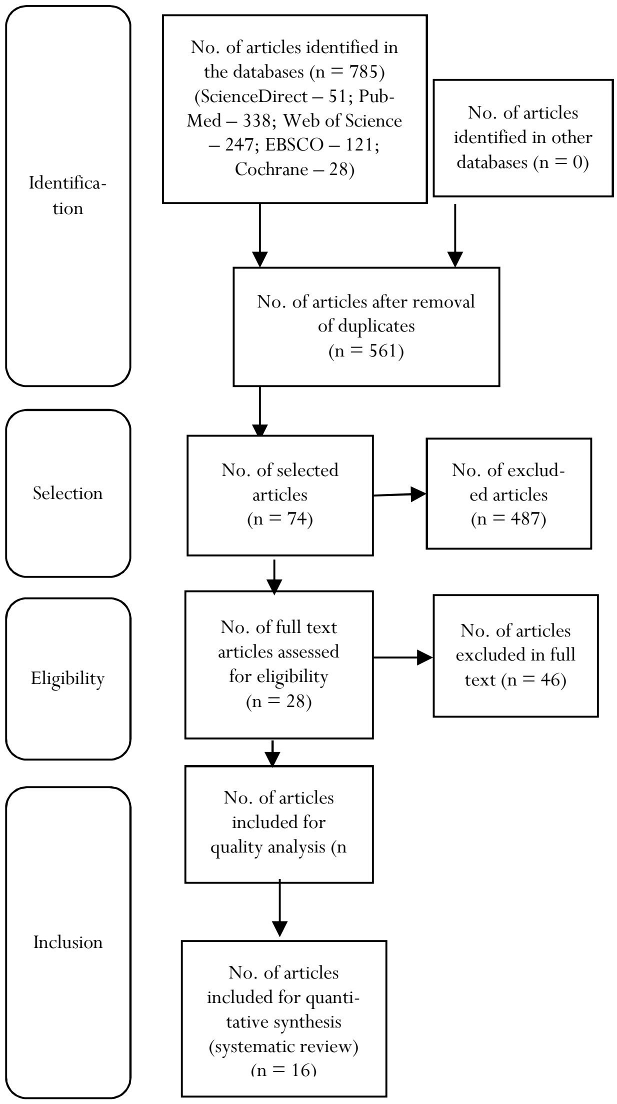

Figure 1 - Diagram of the article selection process

The database search resulted in 785 potential relevant publications (PubMed - 338 publications; Web of Science - 247 publications; EBSCO - 121 publications; ScienceDirect - 51 publications; Cochrane - 28 publications). After the removal of duplicates, the screening of titles, abstracts and full texts was performed according to the previously defined eligibility criteria. The screening process was carried out by two authors independently, situations of disagreement were resolved through discussion and, when necessary, with recourse to a third author (e.g., Mercê et al., 2021). Sixteen articles were included, which were qualitatively assessed using the STROBE scale (Vandenbroucke et al., 2007).

Data Extraction

Data were retrieved by one author and confirmed by another author (e.g., Mercê et al., 2021). The following information was extracted from each study: author(s), study design, age and population studied, test instrument for DCD, instrument for measuring physical activity, results obtained in the study and conclusions drawn from the study.

Analysis of the Quality of Articles

The quality assessment of the 16 studies included was independently performed by the two authors, using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) scale (Vandenbroucke et al., 2007). This scale assesses the quality, validity and bias of each article. Each criterion (of the 22) received a score of zero (0) or one (1). After all the evaluation of the defined criteria, each article has a score between 0 (zero) and 22 (twenty-two). The final score is elaborated through the average of the scores among reviewers. As in previous literature, the score was transformed into three categories by percentage: "A" - when the study fulfils more than 80% of the established criteria; "B" - when the study comprises between 50% and 80% of the criteria; and "C" - when the study fulfils less than 50% of the eligibility criteria (Elm et al., 2007).

Results and Discussion

Study Characteristics

The studies analyzed for this review were characterized according to the study design, intervention population, diagnostic instrument of DCD and physical activity measurement instruments (Table 1). Of the 16 studies included for review, regarding the experimental design, nine are cross-sectional studies, five are case-control studies and one is a cohort study.

Table 1.
Characterisation of the studies analysed

Authors (year)	Study design	Population	DCD Screening	PA Measurement	Main results	Main conclusions
King-Dowling (2019)	Case-control study	589 children (aged 4-5) - 111 with pDCD and 177 with rDCD	MABC-2	Accelerometer	Minimal differences (p=0.31) in moderate and vigorous PA between children with pDCD (M=71.2min/day), rDCD (M=71.4min/day) and without DCD (M=72.0min/day) ; Differences in PA practice may increase over time; Children with pDCD practice moderate to vigorous PA but for less time than TD children (p=0.04)	Deficits in physical fitness may affect the ability to cope with high-intensity activities; PA deficits are not present in the first years of a child's life (they manifest themselves more in infancy and adolescence)

Cermak (2015)	Cross-sectional study	118 children (aged 6-11) - 53 with DCD	MABC-2	Participation in Physical Activity and Sedentary Behaviour Questionnaire and Accelerometer	Children with DCD have lower participation in PA ($p<0.05$); Children with DCD have significantly lower scores in PA through the use of the accelerometer	Low levels of PA are reflected in low physical condition; Children with DCD show more time in sedentary behaviours
Raz-Silbiger (2015)	Cross-sectional study	77 children (aged 6-11) - 22 with DCD	MABC-2	Physical Activity - Participation Questionnaire (PQ)	Children with DCD participate longer in sedentary activities (mean=31.6h/week) than in vigorous (mean=8.4h/week) or moderate (mean=1.3h/week) activities; The worse the performance on balance tasks, the more sedentary activities the child participates in (r=-0.46. p=0.03)	Moderate negative correlation between the no. of activities practiced during school days and the dimension of quality of life at school (r=-o.41. $p<0.05$)
Beutum (2013)	Cross-sectional study	18 children (aged 7-11)	MABC-2	Accelerometer	Children with DCD participate in fewer structured activities than their peers; Children with DCD participate less in moderate and vigorous PA (AVERAGE VALUES: DCD=6.5%, control=9.7%, p=0.04)	Children with DCD are more likely to participate in PA if their primary caregiver does so; Children with DCD have more sedentary time; Muscle strength may be associated with time in moderate and vigorous PA in children with DCD; Strength training may be beneficial to increase PA intensity
Oudenampsen (2013)	Case-control study	76 children (aged 7 to 12) - 38 with DCD	DSM-IV (MABC)	The Modifiable Activity	Children with DCD participate fewer hours/week ($p<0.05$) in general (AVERAGE VALUES: DCD=4.5h/week, control= 5.8h/week), unorganized, vigorous leisure-time PA; Only 31.6% of children with DCD achieve the 1 hour/day PA recommendations; Children with DCD participate less in vigorous PA	Children with DCD only choose activities that make them feel comfortable; vigorous PA (such as cycling or rowing) should be taught with the intention that participating is more important than winning; Children with DCD have lower aerobic capacity
Noordstar (2014)	Cross-sectional study	69 children (aged 7 to 12) - 31 with DCD	MABC-2	Modifiable Activity Questionnaire	Children with DCD participate less in total PA (AVERAGE VALUES: DCD=3.41hours/week, control= 5.77hours/week, $p<0.05$)	Children with DCD have high perceptions of their athletic ability
Cairney (2017)	Cohort study	2117 children (aged 9-10) - 97 with pDCD (wave 1)	BOT - Short Form	The Participation Questionnaire (PQ)	Children with pDCD participate in fewer free activities, organised sports and PA overall than TD children	Children with pDCD have lower VO2 peak than children with TD
Cairney (2012)	Cross-sectional study	578 children (aged 9 to 13) - 44 with pDCD	BOTMP - Short Form	The Participation Questionnaire (PQ)	pDCD children and adolescents are generally less active (AVERAGE VALUE: DCD = 15.4%, control = 19.72%, $p<0.001$); Participation in PA decreases with age and/or task complexity	Low levels of PA may lead to higher levels of fat mass in children/adolescents
Faught (2013)	Case-control study	126 children (aged 11-13) - 63 with pDCD	MABC-2	Accelerometer	Children with pDCD show significantly different levels of PA ($p<0.05$) than their peers (MpDCD=176865.3 steps/day and Mcontrol=210949.3 steps/day)	Children with pDCD show a significant difference ($p<0.01$) in the percentage of fat mass (AVERAGE VALUES: %FMpDCD=28.5% and FMControl=20.3%)
Silman (2011)	Case-control study	122 children (aged 12-13) - 61 with pDCD	MABC-2	Accelerometer and CSAPPA	DCD children are less active compared to their peers ($p<0.05$); DCD children are less likely to participate in PA	DCD children perceive themselves to be less competent in basic physical abilities and also in physical skills; Teachers and parents are important in emphasising daily PA practice
Baerg (2011)	Cross-sectional study	110 children (aged 12-13) - 32 with DCD	BOTMP - Short Form	Accelerometer	Boys with DCD are significantly less active than children in the control group ($p<0.05$)	Poor motor coordination associated with DCD has a negative influence on PA in boys (but not explained in girls)
Kwan (2016)	Case-control study	103 children (aged 12-13) - 49 with pDCD	MABC-2	Accelerometer	Children with DCD are consistently less active during childhood to mid-adolescence; Children with DCD perform significantly less moderate and vigorous PA compared to TD children ($p<0.05$); Children with DCD use about 25 minutes/day in moderate and vigorous PA (consistent over 2 years)	Sedentary time and PA patterns are similar for children with and without motor coordination difficulties in both countries
Li (2018)	Cross-sectional study	1206 children (aged 12-14) - 79 with pDCD	BOTMP-Short Form	Physical Activity - Participation Questionnaire (PQ)	Children with DCD have poorer motor coordination and consequently lower levels of PA ($p<0.05$)	The motor difficulties characteristic of DCD that inhibit children from doing PA may, in the future, cause frustration, feelings of failure and eventually deteriorate mental health
Kwan (2013)	Cross-sectional study	61 children (aged 13-14) - 19 with pDCD	MABC-2	Accelerometer	DCD children (especially boys) spend significantly less time in moderate to vigorous PA (AVERAGE VALUES: DCD=18.70min/day, control=36.59min/day, $p<0.01$)	pDCD children are less motivated to PA than their peers; pDCD children do not find PA enjoyable and do not believe in its importance; Children's perceived social influences/pressures from teachers positively affects time spent in moderate and vigorous PA
Batey (2014)	Cross-sectional study	105 children (aged 13-15) - 29 with pDCD	MABC-2	Accelerometer	Children with poor motor coordination spend significantly less time than peers in moderate and/or vigorous PA (AVERAGE VALUES: pDCD=18.8min/day, control=28.6min/day, p=0.017); DCD is associated with low levels of PA in boys (but not strongly associated in girls)	Differences in PA levels between genders may be explained due to social pressures and developmental stages; PA in girls decreases dramatically during adolescence
Barnett (2013)	Descriptive study	8 children (aged between 13 and 15) with DCD	MABC-2	Physical Activity - Participation Questionnaire (PQ)	Children with DCD participate in fewer recreational activities, organized sports and/or games than their peers	Children with DCD want to be more active; Anxiety provoked by motor performance leads children to have little motivation for PA; Peer com-

				ments negatively affect PA practice in children with DCD; Living in a rural setting can be a limiting factor for PA practice; PE Teachers not well qualified to work/motivate children with DCD to PA practice; Parents' key role in managing time for children's PA.

Note: PA- physical activity; M-mean; TD- typical motor development; %FM- percentage of fat mass; pDCD- probable DCD; rDCD- at risk of DCD

In most of the studies, the MABC-2 test battery (used in eleven studies) was the most employed instrument to diagnose DCD, and the DSM-IV appendix test was also utilized once. Another battery of tests used in four studies was the BOTMF/BOT short form.

Quality Assessment of Studies

As the quality of the articles was assessed using the STROBE scale (Vandenbroucke et al., 2007), all sixteen articles were analyzed and scored according to twenty-two criteria. The final score for most articles was between 17 and 22, with 14 articles in category A (Baerg et al., 2011; Batey et al., 2014; Beutum, Cordier, & Bundy, 2013; Cairney, Kwan, Hay, & Faught, 2012; Cermak et al., 2015; Faught, Demetriades, Hay, & Cairney, 2013; King-Dowling et al., 2019; Kwan, Cairney, Hay, & Faught, 2013; Kwan, King-Dowling, Hay, Faught, & Cairney, 2016; Li et al., 2018; Noordstar et al., 2014; Oudenampsen et al., 2013; Silman, Cairney, Hay, Klentrou, & Faught, 2011) and 2 articles in category B (Barnett, Dawes, & Wilmut, 2013; Raz-Silbiger et al., 2015). According to the previous literature, we included all articles with a classification equal to or greater than 50%, that is, articles A and B for review (Bastuji-Garin et al., 2013). With this division by categories, it is possible to verify that 87.5% of the articles fit into the highest category of the scale, thus establishing a strict criterion in the quality of the articles included in the review.

Assessment tools

DCD is a problem affecting children's motor skills and is associated with low levels of physical activity, a fact which was observed in the 16 studies analyzed. Physical activity was measured using direct and indirect instruments: 9 studies used accelerometers (Baerg et al., 2011; Batey et al., 2014; Beutum et al., 2013; Faught et al., 2013; King-Dowling et al., 2019; Kwan et al., 2013; Kwan et al., 2016; Silman et al., 2011); 5 studies used The Participation Questionnaire, which consists of a child self-completion questionnaire for measuring children's participation in the different domains of physical activity, between ages 8 to 16 years (Barnett et al., 2013; Cairney et al., 2012; Li et al., 2018; Raz-Silbiger et al., 2015); 2 studies used The Modifiable Activity, which measures current physical activity habits of children in relation to previous week and previous year, for ages between 12 to 16 years (Noordstar et al., 2014; Oudenampsen et al., 2013); 1 study used the Participation in Physical Activity and Sedentary Behaviour Questionnaire (The University of Massachusetts – Amherst Physical Activity and Sedentary Behaviour Questionnaire and The Youth Activity Questionnaire), which measures the parents' perception of children's recreational activities, for youth (Cermak et al., 2015); and another study used the Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA) (Children’s Self-Perceptions of Adequacy in and Predilection for Physical Activity), a questionnaire that aims to analyse children's self-perception of performance and their desire to participate in physical activity, for ages between 9 to 16 years (Silman et al., 2011). Two of the studies reviewed (Cermak et al., 2015; Silman et al., 2011) used both instruments for assessing physical activity (accelerometer and questionnaire).

Accelerometery

When measuring physical activity using an accelerometer, its use is recommended over a period between 4 and 9 days, however, it proved to be more effective when used for 7 days (Penpraze et al., 2006), in order to verify differences between weekdays and weekend days (e.g., Aguilar-Farias, Martino-Fuentealba, & Chandia-Poblete, 2019). The majority of the analyzed studies used the 7-day measurement mark, as a base parameter; however, two of the studies did not follow this guideline: one of the studies analyzed physical activity only for 5 days (Cermak et al., 2015) and another measured between 8 and 14 days (Beutum et al., 2013). In this type of data collection, several locations are recommended to position the accelerometer: i) in the lumbar area (L4, L5 or 5 centimetres to the left of it or sacrum); ii) in the hip area (greater trochanter); iii) in the upper part of the iliac crest; or, iv) in the waist area (smaller area between the lower edge of the costal grid and the iliac crest) (Camomilla, Bergamini, Fantozzi, & Vannozzi, 2018; Nilsson, Ekelund, Yngve, & Söström, 2002; Stewart, Marfell-Jones, Olds, & Ridder, 2011; Westerterp, 1999). Nilsson et al. (2002) advocate that the placement of accelerometers in children should be in the lumbar area, as it presents a higher level of comfort for them. In the articles analyzed the accelerometers were placed on the right pelvis (Kwan et al., 2013; Kwan et al., 2016), around the pelvis (King-Dowling et al., 2019), at the level of the left iliac crest (Beutum et al., 2013) and in a flexible belt placed on the hip at the mid-axillary line (Baerg et al., 2011). In the studies by Cermark et al. (2015), Faught et al. (2013) and Silman et al. (2011) it was not possible to verify the location of accelerometer placement in children.

Questionnaires

As for the measurements by indirect instruments (questionnaires), the most used was The Participation Questionnaire (see 3.3. Assessment tools). This questionnaire assesses the child's participation in different physical activity domains, composed of 63 items, and is completed by the child. The Modifiable Activity is a questionnaire completed jointly by parents and children, which assesses the child's physical activity over the past year, the past week, and extreme levels of inactivity. The CSAPPA is a 20-item questionnaire, also completed by the child, that assesses self-perception in performance efficiency and the desire to participate in physical activity. The Participation in Physical Activity and Parenting Behaviour Questionnaire is a questionnaire filled in by parents considering their perception of their children's level of physical activity.

The use of this indirect measurement instrument to measure the physical activity behaviour, entails an error associated with the type of measurement and the instrument itself. Not being a direct measure, the participant's answers and, consequently, the results, will depend on the correct interpretation of the questions (Alderman & Salem, 2010). Recognizing that this issue can be especially sensitive in children, who are still developing their interpretive and linguistic skills, part of these questionnaires is filled in with the help of parents or exclusively by parents. In the present review, four different questionnaires were used to assess physical activity, part of them answered by children, others by children and parents yet others only by parents. This different form of filling in can condition the comparison of results. It should also be noted that, as they aim at different ages, the questionnaires also include different questions or, even if similar, questioned in a different way. Thus, although it is possible to generally compare the results from various questionnaires, it is necessary to interpret them with some caution.

Physical Activity Results

In studies where accelerometers were used, it is possible to verify different results that converge in a single evidence, namely, Batey et al. (2014) and Kwan et al. (2013; 2016) found that children with probable DCD (pDCD) participate significantly less time (minutes per day) in moderate to vigorous physical activity (MVPA) than their typical development peers ($\rho=0.01$, $\rho<0.01$ and $\rho<0.5$, statistical values presented in the order of the referred authors). Batey et al. (2014) found that, on average, children with pDCD were moderately to vigorously active for 18.8±10.3 min/day, in contrast to typically developing children, who were active for 28.6±19.6 min/day. On their turn, Kwan et al. (2013) verified similar numbers, with pDCD children spending 18.7±14.0 min/day in MVPA, and their peers spending 36.59±27.44 min/day, an even bigger difference. This finding is in accordance with the previous review (Rivilis et al., 2011). Kwan et al. (2016) found that children with DCD are persistently less active from childhood to mid-adolescence, using about 25 min per day in MVPA, and this was a consistent value over the 2-year duration of the study. Baerg et al. (2011), Cermal et al. (2015), Faught et al. (2013), and Silman et al. (2011) found significantly less physical activity time in children with DCD ($\rho<0.05$). Additionally, Beutum et al. (2013) found that children with DCD participate in fewer structured physical activities than those with TD.

Contrary to the results obtained in the aforementioned studies, which used the direct accelerometry method, King-Dowling et al. (2019) found no differences ($\rho=0.31$) in levels of moderate and vigorous physical activity between children with probable pDCD (pDCD) ($\bar{x}=71.2\pm19.4$ min/day), at risk of pDCD (rDCD) ($\bar{x}=71.4\pm18.7$ min/day) and with TD ($\bar{x}=72.0\pm20.5$ min/day). However, children with pDCD practice moderate and vigorous physical activity for less time than children with TD ($\rho=0.04$). These deficits in physical activity practice are not present in the first years of the child's life, being more impactful from childhood and adolescence onwards (King-Dowling et al., 2019).

In studies where The Participation Questionnaire was used, it was also possible to verify that children with DCD and children and adolescents with pDCD, in addition to poorer motor coordination, show lower levels of physical activity than TD children with values of $\rho<0.05$ (Cairney, Veldhuizen, King-Dowling, Faught, & Hay, 2017) and $\rho<0.001$ (Li et al., 2018). Additionally, participation in physical activity also decreases with the increasing of child age and/or motor task complexity. Raz-Silbiger et al. (2015) found that children with DCD have more sedentary activities ($\bar{x}=31.6\pm13.8$ hours/week) than vigorous activities ($\bar{x}=8.4\pm5.5$ hours/week during the school year and $\bar{x}=9.7\pm9.0$ hours/week during the summer holidays) or moderate activities (during the school year $\bar{x}=1.3\pm1.5$ hours/week; and, during the summer holidays $\bar{x}=0.7\pm2.4$ hours/week). They also found that a greater number of sedentary activities is inversely related to a lower performance on balance tasks ($\rho=0.03$).

With the same questionnaire, regarding the type of activities performed by children, Barnett et al. (2013) found that children with pDCD and DCD participate less in free activities, organized sports, recreational activities and games than those with typical motor development. Raz-Silbiger et al. (2015) found, in children with DCD, a moderate inverse correlation between the number of activities practiced during school days and the quality-of-life dimension at school ($r=-0.41$, $\rho<0.05$).

Using The Modifiable Activity questionnaire, it was also possible to verify that children with DCD participate significantly fewer hours per week ($\rho<0.05$) in total physical activity with mean values of 4.5±3.5 h/week (Oudenampsen et al., 2013) and 3.41±1.88 h/week (Noordstar et al., 2014), which included the unorganized, vigorous and leisure physical activity, than children in the control groups mean values of 5.8±2.8 h/week (Oudenampsen et al., 2013) and 5.77±2.75 h/week (Noordstar et al., 2014). It was also possible to verify that only 31.6% of the children with DCD reach the physical activity recommendations of one hour per day (Oudenampsen et al., 2013).

Gender differences

As previously mentioned incidence of DCD is more common in male children, although (Villa De Gregorio et al., 2019), as Batey et al. (2014) stated, gender comparisons are difficult because children have different motor and biological ages. Perhaps for this reason the comparison of physical activity behaviour between gender was not explored in the previous systematic review of Rivilis et al. (2011). Generally, female children with TD are less active than male children, and there are even significant differences during adolescence (Rodríguez-Fernández, Rico-Díaz, Neira-Martín, & Navarro-Patón, 2020; Schlund, Reimers, Bucksch, Linder, & Demetriou, 2021). However, in the study of Batey et al. (2014) the opposite was found for children with DCD; the authors found that control males spent 4% of their time in moderate to vigorous activity (MVPA) and the pDCD males just spent 2%, while both females with and without pDCD spent 3%. The gender variable revealed a significant conditional effect on the MVPA in pDCD children (ρ=0.04). Authors consider that because physical activity is linked to social pressures, the experience that children have during physical activity may vary between genders; male children with DCD show a negative reaction to social pressures from their peers, and this reaction is mirrored in lower levels of physical activity (Batey et al., 2014). Male children tend to find physical activity uninteresting, demotivating and embarrassing (Kwan et al., 2013), while female gender children, on the other hand, cope better with social pressures regarding their athletic abilities, making it easier to engage in physical activity (Batey et al., 2014).

Impact of physical inactivity on children's health

The results of the Participation in Physical Activity and Sedentary Behaviour Questionnaire (Cermak et al., 2015) and CSAPPA (Silman et al., 2011) will be presented together with the results obtained using the accelerometer. Through the analysis of the results, it is possible to draw some indicators, which are based on the children's level of physical activity, that have repercussions on other important levels for the daily life of the child with pDCD. As verified in Rivilis et al. (2011) review, children with DCD and pDCD have low levels of physical activity and low fitness (Cermak et al., 2015), lower aerobic capacity (Oudenampsen et al., 2013), lower peak VO2 (Cairney et al., 2017) and higher percentages of fat mass (ρ<0.01) (Faught et al., 2013); in (Cairney et al., 2012) for both children and adolescents. These limitations may affect their ability to withstand high intensity activities (King-Dowling et al., 2019), which in turn may lead to an increase in sedentary behaviour. The child thus ends up entering a cycle of negative influence: lower physical condition - less physical activity practice - worse composition condition - lower physical condition - even less physical activity practice, and so on (Stodden et al., 2008). Children with DCD end up being more likely to be overweight and obese, restarting another negative cycle but now of diseases, since these body composition conditions predispose them to develop metabolic pathologies such as diabetes or cardiovascular diseases (Rivilis et al., 2011).

During adolescence physical activity levels in pDCD males decrease dramatically (Batey et al., 2014). Baerg et al. (2011) also found that, in the male gender, poor motor coordination has a negative influence on physical activity and no information was given about the female gender. At the psychological level, low levels of physical activity in children with DCD may cause future frustration, feelings of failure, and eventual deterioration of mental health (Li et al., 2018), lack of motivation (Kwan et al., 2013) and increased anxiety (Barnett et al., 2013). Low levels of physical activity practice in children with DCD are linked to greater time in sedentary behaviours (Beutum et al., 2013; Cermak et al., 2015); however, in the case of the study by Kwan et al. (2016), in the countries studied (United States of America and Israel) sedentary time is similar between children with and without motor coordination difficulties.

Factors influencing the practice of Physical Activity by children with DCD

The practice of physical activity by children with impaired motor development is influenced by the feelings that the activities bring to them, the activities that make children feel comfortable are chosen (Batey et al., 2014); being that children with pDCD do not find the practice of physical activity enjoyable and do not recognize its importance (Kwan et al., 2013); this discussion had already been addressed in the review of Rivilis et al. (2011). Thus, Oudenampsen et al. (2013) argue that children should be educated for participation, not victory, in some form of physical activity.

One of the influencing factors on physical activity practice is the role of caregivers and educators. Children with DCD are more likely to practice some type of physical activity if their primary caregiver also practices some type of physical activity (Beutum et al., 2013). They are also the ones who play a key role in managing physical activity practice time (Barnett et al., 2013). Silman et al. (2011) refer the importance of daily emphasis on physical activity practice by caregivers and teachers, and this idea is reinforced by Kwan et al. (2013), who state that social pressures or influences perceived by the child from teachers positively affect the time spent in moderate and vigorous physical activity.

When talking about physical activity in children there is always the idea that children have some level of practice, due to physical education classes; however, and despite the teacher involvement being helpful in motivating children with DCD to be physically active, if the teacher is not aware of the DCD condition, he/she may view the student as lazy and not adjust his/her interaction. Unfortunately, it is unlikely for physical education teachers to have special information about DCD, in general they are not skilled (or poorly skilled) in working and/or motivating children towards physical activity practice (Barnett et al., 2013). There is clearly a need to inform and train these teachers, as well as family doctors (Gaines et al., 2008).

Study Limitations

There are some methodological considerations in the studies analyzed that require attention in future investigations with children and adolescents with DCD. In the design of the studies, only one study with a longitudinal design was found. Longitudinal studies allow verifying the effect of interventions for the practice of physical activity in DCD.

Considering the use of accelerometers in several studies, one of the limitations is related to the criteria for placing the accelerometers. Two of the studies reviewed did not present the location of the accelerometer placement (Faught et al., 2013; Silman et al., 2011), this information is crucial to ensure the validity of the methodology used, so it is recommended that this information be clearly reported in future studies. All other studies presented this information, and a diversity of placement sites was verified, so it is necessary to define a standard location for accelerometers when measuring physical activity in children and adolescents, namely considering the comfort criterion. For the measurement of physical activity in children and adolescents, it is also necessary to define a standard duration in the use of accelerometers, regarding days and time interval per day. Standardizing the criteria for duration and place of placement of the accelerometer will allow meta data analysis, further research is needed to this end.

The use of questionnaires, as a tool of indirect measurement to assess physical activity, also represent a limitation. This retrospective methodology has its own limitations, namely the possible misinterpretations of the questions; the recall risk, i.e., the participants could not remember accurately the details asked (Sedgwick, 2012); and, the overestimation in the self-report measures with children and adolescent, resulting from the desire to correspond to the social desirability (Welk, Corbin, & Dale, 2000). Finally, the comparison between different questionnaires also represents a limitation, since the questions are formulated differently and, therefore, can also be interpreted and answered differently.

Conclusion

DCD is a limiting factor in levels of physical activity practice, being generally low. The trend points towards less moderate, vigorous, structured and/or organised physical activity. Low levels of physical activity practice are associated with high values of sedentary behaviours, which are even higher than those of moderate and/or vigorous physical activity practice. Male children with DCD have lower practice than females. Low levels of physical activity practice in children with DCD may bring several psychological problems, besides lower aerobic capacity, lower physical condition, lower VO2 peak and higher percentages of fat mass, during childhood and adolescence.

Parents/guardians and teachers have been found to play a very important role in involving children with DCD in physical activity at school, at home or during leisure time.

There is a great diversity in the measuring instruments applied, so there is an urgent need to standardize the criteria for the use of accelerometers and questionnaires, in order to allow meta-analysis.

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