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Physiological characteristics, self-perceptions, and parental support of physical activity in children with, or at risk of, developmental coordination disorder

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A B S T R A C T

Children with low movement proficiency have been identified as having poorer physiological and psychosocial outcomes; however, the varied measurement approaches used to assess these outcomes have varied resulting in conflicting evidence regarding the presence and magnitude of differences compared to Typically Developing (TD) children. Additionally, there has been limited research into the role of parental support for physical activity (PA) in this group. We compared children with varying levels of movement proficiency on physiological characteristics and self-perceptions regarding PA. In addition, these children's parents were compared on physiological characteristics and support of their children's PA. Children (N = 117) aged 6 to 12 years, along with their parent/guardian, participated in this study. Children were classified according to the Movement Assessment Battery for Children-2 test (Typically Developing (TD) = 60; At Risk = 19; Developmental Coordination Disorder (DCD) = 38). Children's PA, muscle strength, cardio-respiratory fitness (CRF), body composition, and self-perceptions regarding PA were assessed, with parents assessed on CRF, body composition, and PA support. Compared to TD children, children with DCD had lower PA (p = 0.036), predilection ($p \leq 0.001$) and adequacy ($p \leq 0.001$) regarding PA, higher body fat percentage (p = 0.019), and received less logistic support (i.e., transportation) from their parents (p = 0.012). TD children had increased muscle strength compared to the DCD ($p \leq 0.001$) and At Risk ($p \leq 0.001$) groups. Results indicated that, relative to TD children, children with DCD have multiple physiological deficits, receive less parental logistic support for PA involvement, and report lower scores on psychological constructs that are predictive of PA involvement.

What this paper adds?

The study provides a comprehensive, three-group approach to assessing variables that influence physical activity, including objectively-measured physiological factors, psychosocial factors, and levels of parental support. Our results highlight that children in the DCD and At Risk groups differ not only from Typically Developing children but also from each other, with children with DCD experiencing deficits across multiple domains. This study highlights the importance of appropriately identifying whether children have, or are at risk of, low movement proficiency, in order to better address the deficits experienced by these children. These findings

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also provide information that may guide best practice exercise (or physical activity) interventions in this population.

1. Introduction

Regular childhood physical activity (PA) has well established associations with improved physical health and psychological well-being (Janssen & Leblanc, 2010). During childhood and adolescence, higher PA levels also correlate positively with engagement and achievement in school, protect against obesity, and play an important role in determining lifelong activity patterns (Cooper et al., 2015; Telama et al., 2005). Even though the benefits of PA are well known (O'Donovan & Shave, 2007), research has shown a steady decline in PA participation rates after the age of five (Cooper et al., 2015). As a result, there is an urgent need to better understand the characteristics of children not engaging in PA, along with those at risk of reduced participation.

There are a variety of individual (e.g., physical, developmental, behavioural) and external (e.g., family support, access to PA facilities) factors that contribute to child and adolescent PA participation (Trost, Pate, Ward, Saunders, & Riner, 1999). One such factor is movement proficiency, which has been shown to support childhood and adolescent PA participation (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009). Movement proficiency represents the extent to which individuals can competently perform movement skills, and during childhood, movement proficiency not only provides the foundation for PA participation (Barnett et al., 2009; Okely, Booth, & Patterson, 2001), it also aids in the development of skills necessary for popular forms of adult PA (Okely et al., 2001). Children with low movement proficiency represent a subset of children who often have difficulties engaging in regular PA (Rivilis et al., 2011). Low movement proficiency that is not associated with any other identifiable movement-related condition is typically diagnosed as Developmental Coordination Disorder (DCD). DCD is a neurodevelopmental disorder in which the acquisition and execution of coordinated motor skills is substantially below that expected for age. It is characterised by difficulties with fine and/or gross motor skills, and can impact on the performance of activities of daily living and participation in academic, leisure, and play activities (American Psychiatric Association, 2013).

Importantly, children with DCD are less likely to engage in adequate amounts of PA, and are therefore more likely to experience negative health outcomes (Batey et al., 2014; Faigenbaum, Lloyd, & Myer, 2013).

Given the association that exists between movement proficiency and PA participation, it is not surprising that recent research has demonstrated that children with DCD are less physically active compared to their typically developing (TD) peers (Batey et al., 2014; Rivilis et al., 2011). As well as limiting opportunities to accrue PA-induced health benefits (Batey et al., 2014; Faigenbaum et al., 2013), this lack of PA among children with DCD has also been shown to contribute to deficits in other important physiological characteristics, including lower cardio-respiratory fitness (CRF), reduced muscle strength, and increased body fat – when compared to their TD peers (e.g., Li, Wu, Cairney, & Hsieh, 2011; Rivilis et al., 2011; van der Hoek et al., 2012).

Developing a comprehensive understanding of the physiological characteristics of children with DCD is important given that these children (a) experience difficulties developing and performing movement skills, (b) are less active than their peers, and (c) display reduced performance on several measures of physical fitness. To date though, there have been inconsistencies in physiological evidence (e.g., body composition) among this cohort (Chia, Reid, Licari, & Guelfi, 2013; Chirico et al., 2012). Additionally, variation in the methods used to assess CRF has resulted in discrepant information regarding the exact nature of the fitness-related deficits among children with DCD (relative to TD children). Specifically, assessments that rely on predictive methods, or that have used an exercise modality requiring coordination (e.g., shuttle run tests), and that place children with DCD at significant disadvantage, may not provide accurate estimates of fitness for this population (Ferguson, Aertssen, Rameckers, Jelsma, & Smits-Engelsman, 2014; van der Hoek et al., 2012). It is therefore important that researchers employ a range of objective measures to determine physical fitness parameters. Such measures facilitate the accurate detection of potential physiological deficits in children with DCD, and inform best practice physical interventions in this population.

In addition to physiological profiles, the impact of psychosocial and familial factors on PA participation is important to consider. With respect to psychosocial considerations, the assessment of PA-related variables among children with DCD would be incomplete without accounting for important psychological factors that drive movement proficiency and PA engagement. Among TD children, researchers have demonstrated that perceived movement proficiency may mediate the relationship between childhood skill proficiency and adolescent PA or fitness (Barnett et al., 2009). Additionally, between the age of 6 and 12 years (during which time declines in PA are apparent), children become more accurate appraisers of their movement proficiency, resulting – in some instances – in a stronger correlation between perceptions of, and actual, movement proficiency (Harter, 1999). Among children with DCD, perceptions regarding one's movement competence, and one's predilection for PA, are key determinants of PA, and may represent barriers to regular participation; children with DCD, for example, have been shown to report lower perceived competence and enjoyment for PA than their TD counterparts (Batey et al., 2014; Cairney et al., 2005). Indeed, Cairney et al. (2005) contend that PA differences between children with DCD and TD children may be largely a function of discrepancies in their PA-related perceptions. Clearly, it is important when profiling PA-related variables to account for the psychological (and not just physiological) factors that may distinguish children with DCD from their TD counterparts. Guided by these considerations, an aim of this work was to characterise a cohort of children across the spectrum of movement proficiency on relevant psychosocial factors and a range of objectively derived physiological fitness variables.

Given that DCD often emerges in early childhood, and that familial influences on PA are critically important during one's formative years, we also sought to assess relevant familial factors among these children. Regular PA participation during childhood is dependent, in part, upon appropriate encouragement and support from parents/guardians (Sleddens et al., 2012). Parents can support (or thwart) their children's PA, through direct modelling (i.e., their own PA behaviour), providing logistical support (e.g., taking children to places where they can be active; enrolling children into physical activity programs), encouraging participation, restricting sedentary behaviour, and providing a conducive home environment (Trost et al., 2003). Given that physical fitness is an important underlying component for participation in regular PA across all ages (and is a reflection of PA behaviour), understanding potential differences in the physical fitness and modelling behaviour in parents of children with DCD is important. In addition to direct modelling support, Trost et al. (2003) reported that parental support is an important correlate of children's PA, both directly and indirectly through positive relations with children and adolescents' perceptions of competence. Furthermore, Beutum et al. (2013) reported that in children with DCD, primary carer's participation in PA and the carer's perception of the child's motor skill were both significantly related to the percentage of time that the child engaged in moderate to vigorous physical activity (MVPA). These studies provide evidence of associations between parent behaviour/support and children's PA levels. At present though, there are limited examples in the literature using objective PA assessment alongside efforts to (a) document parent PA behaviour and support among children with DCD, or (b) establish comparisons between support provision among children with DCD relative to TD children.

Much is known about the physiological and psychological characteristics of children with DCD. Relative to TD children, those with DCD may be less physically active, have poorer physical fitness, and report less favourable perceptions about PA (Batey et al., 2014; Cairney et al., 2005; Rivilis et al., 2011; van der Hoek et al., 2012). Given that DCD often emerges in childhood, and that parent support is a critical factor for the promotion of children's movement skills and PA, it is possible that there may also be differences in the extent of PA support provided to children with DCD (relative to TD children). To date, however, studies of children with DCD have focused on a specific sub-set of physiological, psychological, and/or support-related concepts (Batey et al., 2014; Beutum, Cordier, & Bundy, 2013; Li et al., 2011). Additionally, research has traditionally compared children in a two-group model (Children with DCD relative to TD children). The aim of this study was to provide a more holistic assessment of PA variables using a three-group approach (Children with DCD, those 'at risk' of DCD, and TD children) whilst measuring a range of key physiological (e.g., body composition, muscle strength, CRF), psychological (e.g., perceived competence, enjoyment of PA), and parent support (e.g., logistical support for, and modelling of, PA) factors. On the basis of existing work (Li et al., 2011; Rivilis et al., 2011; van der Hoek et al., 2012), we hypothesised (a) that there would be significant differences in physiological characteristics across the three groups, with poorer movement proficiency associated with lower CRF, muscle strength, PA levels, and increased body fat (b) parents of children with poorer movement proficiency would exhibit lower CRF and lower levels of PA, and (c) parents of children who are classified as having low movement proficiency would report lower levels of support for PA (when compared to parents of TD children). In line with existing research (Batey et al., 2014; Cairney et al., 2005), we also anticipated that children who are classified as having low movement proficiency would report lower perceived competence, enjoyment, and predilection for PA relative to TD children.

2. Methods

2.1. Participants

One hundred and twenty children aged 6 to 12 years participated in this study; half with low movement proficiency, and half as TD controls matched for age (see Table 1). Along with their parent/guardian (see Table 2), participants were recruited for this study through the community including community-based paediatric exercise programs. Children who were allocated to the DCD group met the four diagnostic criteria for DCD (American Psychiatric Association, 2013). Low movement proficiency was determined using

Table 1
Descriptive characteristics of child participants (N = 117).

Child Characteristics	TD (n = 60) M (SD)	At Risk (n = 19) M (SD)	DCD (n = 38) M (SD)
Age (years)	8.9 (1.9)	8.1 (1.9)	9.2 (1.8)
Body Mass (kg)	30.3 (9.7)	26.5 (6.5)	33.9 (9.9)
MABC-2 (percentile)	57.53 (22.8)	13.1 (22.8)	2.31 (1.85)
PA (MVPA)	197.34 (98.2)[a]	175.29 (87.3)	136.08 (90.7)[a]
Physiological			
Lean Mass (kg)	22.29 (5.0)	20.11 (3.8)	23.42(5.9)
Body fat percentage	21.86 (8.4)[a]	20.11 (6.6)[b]	27.02 (9.7) [a,b]
CRF ($\dot{V}O_2$ peak; ml/kg/min)	39.73 (8.4)	39.38 (6.6)	35.94 (7.7)
Total 5RM strength (kg)	91.20 (24.7)[c,d]	71.05 (17.6)[c]	69.28 (19.9)[d]
Perceptions of PA			
Predilection	28.39 (5.6)[c]	26.52 (6.4)[b]	22.00 (6.8)[b,c]
Enjoyment	10.08 (2.2)	9.89 (2.9)	8.81 (3.5)
Adequacy	22.35 (4.1)[c]	22.10 (4.3)[b]	18.18 (5.7)[b,c]

Note: MABC-2 = movement assessment battery for children-2; PA = physical activity; MVPA = moderate to vigorous physical activity; CRF = cardio-respiratory fitness; 5RM = five-repetition maximum.
[a] Groups are significantly different from each other ($p < 0.05$).
[b] Groups are significantly different from each other ($p < 0.05$).
[c] Groups are significantly different from each other ($p < 0.01$).
[d] Groups are significantly different from each other ($p < 0.01$).

Table 2
Descriptive characteristics of parent participants (N = 93).

Parent Characteristics	TD (n = 42)	At Risk (n = 17)	DCD (n = 34)
Gender			
Male	31	8	11
Female	11	9	23
	M (SD)	M (SD)	M (SD)
Age (years)	42.89 (4.8)	43.6 (4.5)	43.53 (3.5)
Body Mass (kg)	75.82 (18.4)	75.98 (17.5)	79.42 (16.8)
PA (MVPA)	36.66 (20.6)	38.13 (19.6)	32.84 (19.3)
Physiological			
Lean Mass (kg)	47.53 (10.2)	48.91 (10.0)	45.84 (9.3)
Body fat percentage	33.61 (9.1)	29.92 (8.7)	37.65 (9.3)
CRF ($\dot{V}O_2$ peak; ml/kg/min)	30.29 (8.6)	35.08 (9.5)	28.43 (9.5)
PA Support			
Logistic Support	3.38 (0.5)[a]	3.21 (0.6)	3.04 (0.7)[a]
Modelling	3.17 (0.7)	3.39 (0.5)	2.99 (0.7)
Use of Community Resources	3.21 (0.6)	3.14 (0.7)	3.05 (0.6)
Restricting Sedentary Activities	3.53 (0.5)	3.54 (0.6)	3.24 (0.5)

Note: PA = physical activity; MVPA = moderate to vigorous physical activity; CRF = cardio-respiratory fitness; 5RM = five-repetition maximum.
[a] Groups are significantly different from each other ($p < 0.05$).

(a) the Movement Assessment Battery for Children-2 test (MABC-2;Henderson, Sugden, & Barnett, 2007; criterion A); (b) parents reported that their child had difficulty performing recreational and daily activities upon self-referral to the community-based exercise programs (criterion B); (c) the children experienced movement difficulties, which had an onset in the early developmental period (criterion C); and, (d) children with an intellectual disability or medical condition that prevented their participation in PA (e.g., physical injury, cerebral palsy) were excluded (criterion D). No children were diagnosed with Autism Spectrum Disorder (ASD) or Attention Deficit Hyperactivity Disorder (ADHD); however, we evaluated the presence of symptoms of these conditions using the Autism Spectrum Quotient and Vanderbilt ADHD Diagnostic Parent Rating Scale. Written consent was obtained from a parent/guardian, along with ongoing verbal assent from the child, and the relevant human research ethics committee approved the study. An a priori power analysis indicated a sample size of 110 was required to detect significant between-group differences (TD v DCD) based on an anticipated medium effect size (d = 0.62) for PA (Batey et al., 2014).

2.2. Design

Participants attended three, one-hour assessment sessions, each separated by at least two days. During the first session, movement proficiency and muscle strength were assessed, and PA monitors were provided to both parent and child. In the second session, body composition and the fastest walking speed of both parent and child were measured during a $\dot{V}O_2$ familiarisation procedure, and child and parent questionnaires were administered. During the third session, CRF was assessed and parents completed additional symptom questionnaires related to ADHD and ASD. PA monitors were collected on the final session or on completion of the minimum wear time.

2.3. Assessment measures

2.3.1. Movement proficiency

Movement proficiency was assessed using the MABC-2 test, and scored according to the MABC-2 manual in order to gauge the movement proficiency of each child (Henderson et al., 2007). The MABC-2 test assesses proficiency on three main components: manual dexterity; aiming and catching; and balance. For each component, age-adjusted standard scores and percentiles are calculated. Each child received standardised instructions before each task, as outlined in the MABC-2 instruction manual (Henderson et al., 2007). The MABC-2 testing was conducted by an experienced movement specialist. For the purpose of categorical analyses, children whose overall proficiency fell on or below the 5^{th} percentile were placed in the DCD group; while those who fell between the 6^{th} and the 16^{th} percentile were grouped in the 'at risk of DCD' (At Risk) group, and those scoring above the 16^{th} percentile were classified as TD (Henderson et al., 2007).

2.3.2. Indications of autism spectrum disorder

Indications of ASD was measured using the Autism Spectrum Quotient (Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008). The tool is a 10-item parent questionnaire developed to detect autistic traits in children. Statements were rated on a 4-point scale ranging between "Definitely agree" and "Definitely disagree", with reversed scoring on 4 of the 10 statements. Individual scores above 6 indicate the presence of autistic traits and that further assessment should be considered. Scores derived from the Autism Spectrum Quotient have been shown to demonstrate validity evidence in previous reports (Auyeung et al., 2008).

2.3.3. Indications of attention deficit hyperactivity disorder

Indications of ADHD were assessed with the Vanderbilt ADHD Diagnostic Parent Rating Scale (Wolraich et al., 2003), a 45-item symptom instrument including all 18 symptoms that are characteristics of ADHD, where parents rate their child on a 4-point scale ranging from never (0) to very often (3). Scores derived from the Vanderbilt ADHD Diagnostic Parent Rating Scale have been shown to display evidence of concurrent validity and internal consistency (Wolraich et al., 2003).

2.3.4. Moderate to vigorous physical activity

MVPA was monitored using an ActiGraph GT3X-BT activity monitor, which has shown evidence of concurrent validity and intra-/ inter-unit reliability when used to measure PA in TD children and clinical populations (Clanchy, Tweedy, Boyd, & Trost, 2011). Accelerometers were worn on the waist for a minimum of four days (three weekdays and one weekend day) to assess MVPA levels. The activity cut points established by Evenson and colleagues were used to determine minutes spent in MVPA (2296-4012+ counts per minute) for children (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008). For parents, the activity cut points established by Freeson and colleagues were used to determine minutes spent in MVPA (1952+ counts per minute; Freedson, Melanson, & Sirard, 1998). PA data are reported in average daily time spent in MVPA.

2.3.5. Body composition

Body composition was assessed using a full body dual energy x-ray absorptiometry scan (DEXA; Encore 2004, Lunar Prodigy, GE Medical Systems, Madison, WI, USA), which has been shown to be a valid tool for the measurement of body composition in both children and adults (Ackland et al., 2012; Ellis, Shypailo, Pratt, & Pond, 1994). Participants were weighed barefoot and with minimal clothing, and height was measured prior to the scan. Lean mass was used as an estimation of muscle mass and body fat percentage was utilised to determine adiposity.

2.3.6. Cardio-respiratory fitness

Following a treadmill familiarisation session, participants' fastest walking speed was determined through walking on the treadmill at progressive increments of 0.2 km/hr every 20 s, commencing at 4.8 km/hr, until there was a transition from a walk to a run (Tseh, Bennett, Caputo, & Morgan, 2002). In a follow-up session, peak oxygen uptake ($\dot{V}O_{2\ peak}$) was assessed on a breath-by-breath basis using a Cosmed portable analyser (Model K4b2; Cosmed, Rome, Italy). The unit (70 mm x 50 mm x 100 mm; 475 g) was worn in a chest harness and an appropriate facemask (i.e. paediatric or adult size) was fitted. Participants' expired gases were collected via the facemask connecting a sampling line to a biodirectional flowmeter, and then to the O_2 and CO_2 analyser, allowing air flow volumes and fractions of expired oxygen and carbon dioxide to be measured. Prior to the commencement of testing, the unit was calibrated in accordance with the manufacturer's guidelines. Participants then completed an incremental treadmill protocol previously used in a DCD population (Chia et al., 2013), which commenced at 1 km/hr below the previously determined fastest walking speed. The treadmill gradient was increased every two minutes, with a 30 s rest in between stages until volitional exhaustion; heart rate (Polar FT7 monitor) was recorded at the end of each stage. After a period of rest, to ensure a peak was reached, each child completed an additional three minute supra-maximal effort at 110% of the speed that was attained in the $\dot{V}O_{2\ peak}$ test (de Groot et al., 2009). Participants' expired respiratory gases were collected throughout, and ratings of perceived exertion were assessed using a visual scale at the end of each stage (Robertson et al., 2000). The test was considered a peak if participants met two of the following three criteria: respiratory exchange ratio value was greater than 1.00; heart rate equal to or greater than 90% age predicted heart rate max; and volitional exhaustion (Armstrong & van Mechelen, 2008). For the purpose of analyses, participants' $\dot{V}O_{2\ peak}$ corrected to body mass was recorded as an indicator of CRF.

2.3.7. Muscle strength

A five-repetition maximum (5-RM) strength test was administered to assess dynamic maximal strength – via chest press, leg press, and pull down – using specialised seated paediatric weight-supported pin-loaded machines. The 5-RM method is the maximal weight an individual can move through a full range of motion five times, whilst maintaining correct technique (Faigenbaum, Milliken, & Westcott, 2003). Each exercise was verbally explained and demonstrated, and the initial load for each exercise was set at the lowest setting for the purposes of providing a warm up and allowing the child to become familiarised with the equipment. The child was then instructed to perform five repetitions. If the child succeeded, a rest period of three minutes was given and another set was attempted with an increased load based on the child's rating of perceived exertion (Robertson et al., 2000). This process continued for a maximum of five sets so as to minimise fatigue. The 5-RM was recorded as the last resistance lifted in which the participant was able to complete all five repetitions through full range and without loss of technique (as judged by the exercise specialist) (Reynolds, Gordon, & Robergs, 2006). The instructor ended children's participation if their technique failed during a set or if a full repetition was not performed.

2.3.8. Children's self-perceptions

The Children's Self Perceptions of Adequacy in and Predilection for PA (CSAPPA; Hay, 1992) questionnaire was used to determine children's perceptions of their adequacy in performing PA ('adequacy' – 7 items), likelihood of selecting ('predilection' – 9 items) PA, and enjoyment of ('enjoyment' – 3 items) physical education in school. Participants were requested to rate a series of structured alternative statements according to how they felt at that moment in time. For example, children were asked to choose the option that they felt best described them from pairs of statements such as "some kids are among the last to be chosen for active games" and "other kids are usually picked to play first", and were then instructed to indicate whether the selected sentence was either "sort of true for me" or "really true for me". Responses to each item are coded from 1 to 4, where higher numbers represent greater adequacy/predilection/enjoyment. Scores derived from the CSAPPA have been shown to demonstrate strong test-retest reliability (Hay, 1992). Internal consistency estimates (α) for scores derived from each CSAPPA dimension in this study were 0.83, 0.83, and 0.86 for adequacy, predilection, and enjoyment, respectively.

2.3.9. Parents' support for PA

The Activity Support Scale for Multiple Groups (ACTS-MG; Davison, Li, Baskin, Cox, & Affuso, 2011) parent report is a 12-item questionnaire assessing parental support for PA, consisting of four subscales representing logistic support (e.g., taking children to places where they can be active), modelling, use of community resources, and restricting sedentary activities. Parents were asked to respond to statements (e.g., "I take my child to places where he/she can be active") using response options anchored at 1 (strongly disagree) and 4 (strongly agree). Researchers have demonstrated evidence for validity and reliability of scores derived from the ACTS-MG (Davison et al., 2011), and in this study, internal consistency estimates (α) for logistic support, modelling, use of community resources, and restricting access to screen-based activities were 0.65, 0.88, 0.73, and 0.90 respectively.

3. Data analysis

Prior to performing primary analyses, data were assessed for normality and homogeneity. Three child participants (from the 120 recruited) were excluded from all analyses due to being extreme outliers on the body composition variables (i.e., z scores > 3). Of the 117 children included in the final sample, 74 participants were male (TD = 32; At Risk = 13; DCD = 29) and 46 female (TD = 28; At Risk = 9; DCD = 9). Fifteen children (TD = 3; At Risk = 2; DCD = 10) were identified as having traits of ASD, 17 children (TD = 3; At Risk = 4; DCD = 10) exhibited one subtype of ADHD, and three children (At Risk = 2; DCD = 1) exhibited both attention deficit and hyperactivity traits. One child did not complete a body composition assessment due to parent request, and 12 children did not meet the previously stated criteria for a $\dot{V}O_{2\ peak}$; missing data for these children were treated using pairwise deletion. Demographic information for the final sample (excluding outliers and omissions) is presented in Table 1.

Given that any parent may have multiple children participating in the study, analysis on parent-child dyads was computed using the first child who participated in the study (i.e., the first child of that parent to complete the procedure). Of the 99 parents who were recruited, six declined to participate in the parent component of the study (N = 93). With regards to physical outcomes, one parent declined to participate in the body composition assessment, five parents chose not to complete the CRF testing due to illness/injury, and three parents were unable to achieve a $\dot{V}O_{2\ peak}$ (missing data were again treated using pairwise deletion). Demographic information for the final parent sample (excluding outliers and omissions) is presented in Table 2.

In order to compare children's physiological and psychological variables across different movement proficiency classifications, two-way (i.e., 2 × 3; gender x movement proficiency classification) multivariate analyses of variance (MANOVAs) were performed. In the first MANOVA, dependent variables included all physiological indices (i.e., CRF, muscle strength, body composition, MVPA); in the second, dependent variables included children's PA perceptions (i.e., adequacy, enjoyment, predilection regarding PA). Gender was included as a factor alongside movement proficiency classification based on gender differences previously reported for children's PA-related characteristics (Cooper et al., 2015). To examine differences in parent physiological variables and support for child PA (i.e., all variables reported by or collected with parents) according to child gender and movement proficiency classification, separate two-way (i.e., 2 × 3; child gender x movement proficiency classification) MANOVAs were again performed. The first MANOVA included physiological indices as dependent variables (i.e., CRF, muscle strength, body composition, MVPA), and the second included dimensions of parent support for child PA (i.e., logistic support, modelling, use of community resources, and restricting sedentary activities).

4. Results

4.1. Children's physiological characteristics

Analyses revealed significant multivariate main effects for proficiency group, $F(10, 182) = 4.86$, $p = 0.001$, $\eta_p^2 = 0.21$, $\lambda = 0.62$, and gender, $F(5, 91) = 2.54$, $p = 0.034$, $\eta_p^2 = 0.12$, $\lambda = 0.88$, but no proficiency-by-gender interaction effect, $F(10, 182) = 0.59$, p = 0.816, $\eta_p^2 = 0.03$, $\lambda = 0.94$. Univariate follow-up analyses identified that the proficiency group effect was accounted for by significant between-group differences on MVPA, $F(2, 95) = 3.378$, $p = 0.03$, $\eta_p^2 = 0.06$, body fat percentage, $F(2, 95) = 4.31$, $p = 0.016$, $\eta_p^2 = 0.08$, muscle strength, $F(295) = 14.58$, $p = < 0.001$, $\eta_p^2 = 0.24$, and CRF, $F(2, 95) = 3.83$, p = 0.025, $\eta_p^2 = 0.08$, but not lean mass, $F(2, 95) = 1.20$, p = 0.30, $\eta_p^2 = 0.03$.

Post-hoc analysis for MVPA indicated that participants in the DCD group scored significantly lower than TD children (*mean diff* = 52.64, $p = 0.036$, $d = 0.56$; see Table 1 for descriptive output); however, participants classified in the At Risk group did not differ significantly from the TD (*mean diff* = 26.29, $p = 0.608$, $d = 0.28$) or DCD groups (*mean diff* = 26.34, $p = 0.644$, $d = 0.29$). For body fat percentage, children in the DCD group displayed significantly greater body fat percentage than the TD (*mean diff* = 4.96, $p = 0.019$, $d = 0.56$) and At Risk (*mean diff* = 7.31, $p = 0.013$, $d = 0.95$) groups; no significant difference emerged between the TD and At Risk group (*mean diff* = 2.35, $p = 0.584$, $d = 0.31$). For muscle strength, TD children were significantly stronger than both the At Risk (*mean diff* = 22.36, $p = 0.001$, $d = 1.10$) and DCD (*mean diff* = 23.39, $p = 0.001$, $d = 1.10$) groups; no significant difference emerged between the At Risk and DCD group (*mean diff* = 1.03, $p = 0.987$, $d = 0.06$). Finally, although a significant difference in CRF was identified at the univariate level, post hoc follow up demonstrated no significant difference between the TD and At Risk groups (*mean diff* = 0.41, $p = 0.983$, $d = 0.05$); with differences observed between TD and children with DCD only approaching significance (*mean diff* = 4.10, $p = 0.059$, $d = 0.49$).

Although inspection of gender effects was not of substantive importance for addressing our hypotheses, follow up analyses revealed that the gender effect was accounted for by significant differences in body fat percentage, $F(1, 95) = 7.44$, $p = 0.008$, $\eta_p^2 = 0.07$, and CRF, $F(2, 95) = 5.60$, $p = 0.020$, $\eta_p^2 = 0.06$. Females ($M = 26.29$, $SD = 8.63$) had significantly higher body fat percentage than males ($M = 21.90$, $SD = 8.52$) and lower CRF ($M = 36.49$, $SD = 8.59$) than males ($M = 40.17$, $SD = 7.96$). There was no significant different between genders for MVPA, $F(2, 95) = 0.92$, $p = 0.762$, $\eta_p^2 = 0.00$, lean mass, $F(2, 95) = 0.29$, $p = 0.591$, $\eta_p^2 = 0.00$, or muscle strength, $F(2, 95) = 0.43$, $p = 0.837$, $\eta_p^2 = 0.00$.

4.2. Children's self-perceptions

Analysis of differences on children's perceptions of adequacy, predilection toward, and enjoyment of PA revealed significant multivariate main effects for movement proficiency, $F(6, 216) = 3.94$, $p = 0.001$, $\eta_p^2 = 0.09$, $\lambda = 0.81$, but no multivariate main effect for gender $F(3, 108) = 0.86$, $p = 0.462$, $\eta_p^2 = 0.02$, $\lambda = 0.98$, and no multivariate interaction effect $F(6, 216) = 1.00$, $p = 0.423$, $\eta_p^2 = 0.03$, $\lambda = 0.94$. Univariate follow-up analyses revealed that the proficiency group effect was accounted for by significant between-group differences on predilection, $F(2, 110) = 11.57$, $p < 0.001$, $\eta_p^2 = 0.17$, enjoyment, $F(2, 110) = 4.39$, $p = 0.015$, $\eta_p^2 = 0.07$, and adequacy, $F(2, 110) = 7.67$, $p = 0.001$, $\eta_p^2 = 0.12$.

Inspection of post-hoc (i.e., Tukey's HSD) tests for predilection revealed that children with DCD reported significantly lower predilection for PA than their TD (*mean diff* = 6.39, $p \leq 0.001$, $d = 1.02$) and At Risk (*mean diff* = 4.53, $p = 0.030$, $d = 0.68$) counterparts; no significant difference was observed between the TD and At Risk groups (*mean diff* = 1.86, $p = 0.496$, $d = 0.31$). For adequacy, post-hoc tests showed that children with DCD reported significantly lower adequacy perceptions compared to both the TD (*mean diff* = 4.17, $p \leq 0.001$, $d = 0.83$) and At Risk (*mean diff* = 3.92, $p = 0.013$, $d = 0.77$) groups; again, no significant difference was apparent between the TD and At Risk groups (*mean diff* = 0.25, $p = 0.979$, $d = 0.06$). Finally, despite observing a significant effect for enjoyment at the univariate level, post hoc analysis revealed no significant difference between DCD and At Risk groups (*mean diff* = 1.08, $p = 0.37$, $d = 0.33$), with differences between the DCD and TD groups only approaching significance (*mean diff* = 1.27, $p = 0.08$, $d = 0.42$).

4.3. Parent physiological capacity

Analyses revealed no significant multivariate main effects for parents' physiological capacity according to their child's movement proficiency classification, $F(8, 140) = 1.42$, $p = 0.192$, $\eta_p^2 = 0.08$, $\lambda = 0.85$, or their child's gender $F(4, 70) = 0.35$, $p = 0.843$, $\eta_p^2 = 0.02$, $\lambda = 0.98$, and no significant multivariate interaction effect, $F(8, 140) = 0.867$, $\mathrm{p} = 0.546$, $\eta_p^2 = 0.05$, $\lambda = 0.91$.

4.4. Parental support for PA

Analyses of parent support revealed a significant multivariate main effect for child proficiency group, $F(8, 164) = 2.40$, $p = 0.018$, $\eta_p^2 = 0.10$, $\lambda = 0.80$, but no multivariate main effect for gender, $F(4, 82) = 0.83$, $p = 0.512$, $\eta_p^2 = 0.03$, $\lambda = 0.96$, and no multivariate interaction effect, $F(8, 164) = 0.79$, $p = 0.615$, $\eta_p^2 = 0.04$, $\lambda = 0.93$. Univariate follow-up analyses identified that the child proficiency group effect was accounted for by significant between-group differences on logistic support, $F(2, 91) = 3.36$, $p = 0.039$, $\eta_p^2 = 0.07$, but not modelling, $F(2, 91) = 1.69$, $p = 0.191$, $\eta_p^2 = 0.04$, use of community resources, $F(2, 91) = 0.47$, $p = 0.623$, $\eta_p^2 = 0.01$, or restriction of sedentary activities, $F(2, 91) = 0.54$, $p = 0.179$, $\eta_p^2 = 0.04$. Examination of post-hoc tests for logistic support indicated that parents of children with DCD reported providing significantly lower logistic support than parents of TD children (*mean diff* = 0.38, $p = 0.012$, $d = 0.56$); parents of children in the At Risk group did not differ from parents with children in the TD (*mean diff* = 0.22, $p = 0.239$, $d = 0.32$), or DCD (*mean diff* = 0.16, $p = 0.401$, $d = 0.25$) groups.

5. Discussion

The present study focused on testing (a) differences in physiological characteristics and PA-related perceptions between children with DCD, those At Risk, and TD children, and (b) how parents/guardians of these children differ in physical fitness and PA support for their child. Our hypotheses were broadly supported, with analyses revealing significant differences between movement proficiency groups on physiological characteristics, self-perceptions regarding PA, and parental support. More specifically, compared to TD children, those with DCD engage in less MVPA and have lower muscular strength and increased body fat percentage – these results are in line with previous findings (Li et al., 2011; van der Hoek et al., 2012). Interestingly, the At Risk group presented with a singular deficit in physiological capacity - muscle strength - with no evidence of impact on MVPA levels compared to TD children. It is possible the magnitude of the deficit in muscle strength seen in the At Risk group was not substantial enough to impact on MVPA levels, but highlights the importance of early detection and intervention to counteract potential further decline and impact on other physiological characteristics. Results suggest that children At Risk are more like TD children in their physiological characteristics than children with DCD, and providing evidence that a three-group approach may have greater merit than the traditional two-group classification. In addition to differences in multiple physiological parameters, children with DCD also reported lower scores on psychological constructs and were provided with less logistic support than children in the TD or At Risk groups. Our results highlight the importance of appropriately identifying whether children have, or are at risk of, low movement proficiency, as this will enable researchers and clinicians to address the deficits experienced by these children.

Contrary to previous findings (Ferguson et al., 2014; van der Hoek et al., 2012), our results did not demonstrate that children with DCD (or at risk of DCD) had decreased CRF. Potential reasons for the discrepancy in findings are that our study used a laboratory-based assessment method, allowing participants to complete the progressive test at an individualised starting speed. In contrast, previous studies have utilised field-based assessments (e.g., shuttle run tests), typically in the form of group-based exercise modalities requiring significant coordination, placing those with movement difficulties at a disadvantage, as well as the use of predictive equations to estimate $\dot{V}O_{2\ peak}$. Moreover, it might also be possible that children with DCD may not be highly motivated to perform field-based assessments alongside their peers (e.g., Cairney, Hay, Faught, Léger, & Mathers, 2008). Although field-based assessments may correspond more closely to school yard play than lab-based protocols, to better understand the potential physiological challenges experienced by children with or 'at risk' of DCD, an individualised progressive testing protocol may provide a truer representation of CRF.

Similar to previous studies, our results showed differences in both predilection and adequacy regarding PA across groups (Batey et al., 2014; Cairney et al., 2005). Specifically, those with the lowest movement proficiency displayed lower perceived competence with regards to predilection for, and adequacy towards, PA compared to both TD and At Risk groups. This finding indicates that these children are not as confident in their ability to partake in PA, and that given the choice they would choose a sedentary based activity rather than active pursuits.

The second aim of the study was to determine differences in parental physiological capacity and the PA support given to children across movement proficiency groups. It has been well established that parent support can positively or negatively influence PA through several mechanisms (Trost et al., 2003). In contrast to our hypothesis, analyses revealed that irrespective of which proficiency group their child was in, parents demonstrated similar levels of physical fitness and PA modelling behaviours. Our results imply that in seeking effective strategies with which to increase PA levels in children with DCD, targeting parents' physical fitness and PA levels alone may not be efficacious. Although this is one of the first studies to investigate parent modelling behaviours among children with DCD, it has been reported previously that parent modelling alone may be insufficient in influencing TD children's PA levels (Trost et al., 2003).

We observed no differences across parent/guardian fitness and PA modelling; however, analyses did reveal significant differences for parental logistic support (e.g., taking children to places where they can be active; enrolling children into physical activity programs). Specifically, parents of children in the DCD group reported providing significantly less logistic PA support than parents of children in the At Risk or TD groups. There are a variety of factors that could contribute to why parents of children with DCD provide less logistic support, but given that children with DCD have difficulties in physical and psychosocial domains, it may be more challenging for parents to appropriately resource their child's PA participation. It is also possible that parents may provide reduced logistic support for PA simply because they provide greater support in other domains (e.g., accessing allied health services).

The strengths of this study include the range of assessments, the inclusion of children and parents, the three-group approach to quantifying movement proficiency, and the objective measurement of key physiological characteristics. These strengths should be balanced, however, against important limitations and associated future research directions. First, it is worth highlighting that we utilised a cross-sectional approach, and as a result, it is important to acknowledge that we did not seek to provide insight into the nature of the relationships between our variables of interest, and accordingly, it is worth noting that there may in fact be bi-directional relationships between many of these factors (e.g., muscle strength, body fat, and MVPA; motor proficiency and perceived competence). Additionally, whilst participants were screened for potential co-occurrence of symptoms of ASD and ADHD, this study was not powered to detect differences across our physiological and psychosocial variables and potential sub groups with multiple neurodevelopmental conditions such as ADHD + DCD. In the future, it would be particularly worthwhile to adopt prospective or longitudinal designs in which psychological and support-related factors (including potential confounding factors such as socio-economic status) are modelled as predictors of MVPA and other physiological outcomes. As participants volunteered and were recruited from sites including a community based exercise program there is potential for a sampling bias, however we did not see this as a significant limitation given the differences observed. Future work should be done to investigate how community PA programs/interventions can influence changes in child-related psychological and physical outcomes, in addition to affecting changes at a parent/guardian level.

6. Conclusion

The findings of this study demonstrate that children with DCD – relative to TD children – present with deficits across physiological factors (e.g., strength, fitness, motor control, body composition), psychosocial (e.g., perceived competence) factors associated with PA, and levels of parental logistic support for PA. It is our hope that these findings may inform researchers not only as to the assessment methods most suited to identifying characteristics of children with movement difficulties (and their parents), but may also provide the platform for identifying key intervention strategies among this cohort.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ridd.2018.05.013.

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