# BODY COMPOSITION AND GLOBAL SELF-WORTH IN CHILDREN WITH DCD

# RELATIONSHIPS AMONG BODY COMPOSITION, PHYSICAL ACTIVITY, GLOBAL SELF-WORTH AND DEVELOPMENTAL COORDINATION DISORDER IN CHILDREN OVER TIME

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## ABSTRACT

It is well established in the literature that children with developmental coordination disorder (DCD) are more likely to be physically inactive, have unhealthy weight, and report lower perceptions of self-worth than typically developing (TD) children. Physical inactivity, overweight/obesity and low self-worth are important risk factors for many physical and psychological health conditions. The interrelationships among these factors, however, have yet to be explored in children with DCD. There is limited information on change in body composition measures and self-worth over time in children with DCD, the effect of physical activity (PA) on body composition, and whether the combined negative influence of having both DCD and obesity result in poorer conceptions of self-worth. In this dissertation, I present a series of studies that explore the connections among these factors using longitudinal, population-based data on a large cohort of children with and without poor motor coordination. The first study, presented in Chapter 2, describes the results of change in BMI and waist circumference (WC) in children with probable DCD (pDCD) and TD children over a five-year time period, and the effects of sex and PA on this relationship. Chapter 3 describes the results of the relationship between body fat, pDCD, and PA after addressing the measurement-related limitations of the study reported in Chapter 2. Chapter 4 describes the results of self-worth in children with pDCD and overweight/obesity, only pDCD, only overweight/obesity, and the control group at baseline as well as change over time. Collectively, the results show that children with pDCD have a consistently higher BMI, WC, and body fat than TD children. BMI and WC increases over time in children with

pDCD; specifically boys with pDCD show a much accelerated increase in these measures. Scores of body composition measures increase with decrease in self-reported and objectively measured PA, but participation in PA does not explain why children with pDCD are more likely to have excess weight gain. Finally, children with both pDCD and overweight/obesity and children with either of these conditions alone report lower self-worth than the control group, and the change in self-worth between groups remains constant over time.

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## LIST OF ABBREVIATIONS

APA – American Psychiatric Association

BMI – Body Mass Index

BOTMP-SF – Bruininks-Oseretsky Test of Motor Proficiency Short Form

DCD - Developmental Coordination Disorder

DSM-IV – Diagnostic and Statistical Manual of Mental Disorder, Fourth Edition

DSM-5 – Diagnostic and Statistical Manual of Mental Disorder, Fifth Edition

KBIT-2 – Kaufman Brief Intelligence Test - 2

MABC-2 – Movement Assessment Battery for Children – 2

MVPA – Moderate-to-Vigorous Physical Activity

OWT – Overweight

pDCD – Probable Developmental Coordination Disorder

PHAST – Physical Health Activity Study Team

SD – Standard deviation

TD – Typically developing

WC – Waist circumference

## DECLARATION OF ACADEMIC ACHIEVEMENT

Divya Joshi conceptualized the research questions, conducted statistical analysis, and wrote all drafts of the manuscripts.

Cheryl Missiuna was a co-investigator on the PHAST project and a committee member on the dissertation committee. She provided feedback on the completed drafts of the manuscripts.

Steven Hanna was a committee member on the dissertation committee and provided assistance with statistical analysis of the data.

John Hay was a principal investigator on the PHAST project.

Brent Faught was a principal investigator on the PHAST project.

John Cairney was a principal investigator on the PHAST project and a supervisor on the dissertation committee. He provided feedback on all components of the completed manuscripts.

# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

This dissertation explores the relationships among measures of body composition, physical activity, perceived self-worth and time, in children with and without developmental coordination disorder (DCD). After establishing relationships among DCD, time and body composition measures, the next step in this dissertation was to examine the secondary consequence of having both DCD and overweight/obesity on global self-worth, both cross-sectionally as well as over time as children aged from peri-adolescence to adolescence. In doing so, the studies in this dissertation advance previous research in a number of important ways: First, most work in this area has provided a time invariant picture (cross-sectional examination) of select parts of the associations among these factors. A comprehensive examination of the inter-relationships among DCD, time, body composition, physical activity, and perceptions of self-worth in this population has not yet been conducted. As well, this work advances current research by beginning to explore the possibility of multiple disadvantages, in this case motor coordination problems and obesity, and how these accrued disadvantages lead to compounded, negative trajectories in relation to conditions believed to be *secondary* to DCD. Indeed, there is an emergent interest in mapping out the health, social and psychological consequences of children with motor coordination problems (1), and this dissertation was conceived to address this particular knowledge gap in the literature.

The studies presented in this dissertation explore the relations among DCD, body composition, physical activity, and self-worth using longitudinal, population-based data on a large cohort of children aged 8-10 years. Before contacting participants, ethics clearance was obtained from the university research ethics board and the district school board. Child's assent and written informed consent was obtained from a parent or guardian of each child before the child's participation in the study. In cases were a child was identified with pDCD, an assessment report, description of DCD, and information on additional resources to assist in learning more about the disorder were mailed to the parents. Parents were also encouraged to speak with their family physician and arrange for a complete assessment. Teachers were not informed about the child's pDCD status, however they were provided with resources to help children with pDCD cope with their movement difficulties.

The following introduction provides a description of the disorder, review of the literature and the theories linking DCD, physical activity, and body composition, as well as the rationale for undertaking these studies.

### 1.2 Developmental Coordination Disorder

In the past, children with motor coordination problems have been described as being "clumsy" and "awkward". Developmental dyspraxia, sensory integrative dysfunction, minimal brain dysfunction, handwriting problems, motor learning difficulty, hand-eye coordination problems, disorder of attention and motor perception, and minor neurological dysfunction have also been used when referring to these children (2-3).

Some of these terms are considered to be ambiguous or have a negative undertone when used to describe the difficulties experienced by children with motor coordination problems. Using different terms to describe the disorder also makes it difficult to communicate and compare findings of various studies, and design appropriate intervention programs (3). To address these issues it was necessary that a single term be used when describing children with motor coordination problems, and in 1994, at the international consensus meeting held in London, Ontario, experts agreed upon using the term developmental coordination disorder (DCD) (4).

The criteria outlined in the fifth version of the Diagnostic Statistical Manual (DSM-5) are used in diagnosing children with DCD. These criteria include:

A. The acquisition and execution of motor skills is below the age-expected norms. This may be manifested by poor balance, dropping things, or delays in achieving motor milestones (e.g. crawling, and walking) and motor skills (e.g. handwriting, drawing, catching, throwing, and hopping).

B. Deficits in motor skills have a significant and persistent negative impact on activities of daily living, academic achievement, vocational activities, leisure, and play appropriate to a child's chronological age.

C. Onset of symptoms is in the early developmental period.

D. Deficits in motor skills cannot be explained by intellectual developmental disorder or visual impairment, and are not due to other known neurological conditions such as cerebral palsy, muscular dystrophy or degenerative disorder (5).

Depending on whether some or all of the aforementioned criteria are used to identify the cases, prevalence estimates of DCD range from 1.8% to 6% of children (2, 6-7). It is reported that boys are more likely to be affected than girls, although recent studies have reported the prevalence to be similar in boys and girls (6). Also, children born premature and children with very low birth weight are known to be at an increased risk of developing the disorder (8).

### 1.3 Etiology of Developmental Coordination Disorder

Although much has been learned about the functional difficulties experienced by children with DCD, the etiology of DCD is still quite unclear. The cerebellum plays an important role in motor coordination and postural control and, therefore, studies have suggested the involvement of the cerebellum in the etiology of DCD (9-10). Studies have shown that children with DCD have difficulty in performing cerebellar function tests such as finger-to-nose touching and rapid alternating hand movements (10). Children with DCD also have poor motor adaptation suggesting dysfunction of the cerebellum (10). Several other factors including genetic predisposition, environment, and brain damage due to prenatal, perinatal, or neonatal incidents have also been examined to understand their role in the etiology of DCD (11). Studies have shown an association between increased coordination difficulties and incidence of perinatal complications, lower birth weights, and children born premature or were overdue (11). A study using a monozygotic twin design found DCD to be associated with perinatal oxygen perfusion problems (12). This study also found an increased risk of motor problems in a second-born twin than a first-born twin (12). Although the specific causes of motor delays and DCD are unknown, the functional, and health and psychological consequences associated with DCD have been examined extensively.

### 1.4 Secondary Consequences Associated with Developmental Coordination Disorder

The presence of poor motor coordination on its own is insufficient cause for concern. Indeed, it is the impact of motor coordination problems on health, social and individual functioning, including performance at school, that is the basis of concern for parents, teachers, clinicians and children with DCD themselves (1). In other words, it is the fact that DCD gives rise to so many difficulties in participation in activities of daily living, and its association with a wide array of physical and emotional-behavioral problems, that has been described in the literature as secondary consequences, that reflects so poignantly why we should be concerned about DCD.

There is in fact, an extensive literature, documenting some of these secondary concerns in relation to DCD. For example, children with DCD are less likely to participate in team play and sports, physical activity, and be physically fit (13-24), are more likely to be overweight and obese, be ridiculed, report social isolation and loneliness, hold negative perceptions of self-worth, have lower self-esteem, and report psychological problems such as increased anxiety, stress, and depression (25-33). Previously it was believed that children with DCD might grow out of their motor difficulties. However, longitudinal studies have consistently shown that children do not outgrow their difficulties, and without interventions their difficulties persist into adolescence and adulthood (34-35). While children with DCD may learn to perform certain tasks with practice, over time they will still continue to experience difficulties with new age-appropriate tasks. With failure to diagnose DCD and provide intervention, difficulties experienced by children with DCD may lead to employment problems, substance misuse, poor interpersonal skills, and even increased crime in adult life (2).

While children with DCD experience many secondary health consequences, physical inactivity is one particular area of concern. Participation in physical activity is associated with a wide range of positive developmental and health outcomes. Inadequate physical activity conversely is associated with obesity, which in turn is associated with cardiovascular disease, type II diabetes, dyslipidemia, hypertension, cancer, osteoporosis, and depression (36). In order to prevent or lower the risk of these chronic health conditions, interventions are usually designed to promote physical activity. However, some children such as those with motor coordination difficulties may be unwilling to participate in physical activity. Considering that physical inactivity is associated with many negative health consequences, it is important to examine physical activity levels in children with DCD.

### 1.5 Physical (In)Activity and Developmental Coordination Disorder: The Activity-Deficit and Skill-Gap Hypothesis

Physical activity has many beneficial effects on cardiovascular, musculoskeletal, and psychological health (37). Even though physical activity is associated with multiple health benefits, recent guidelines suggest most children are physically inactive and do not meet the physical activity recommendations for their age group (38-39). It is recommended that children aged 5 to 11 years and youth aged 12 to 17 years should accumulate at least 60 minutes of moderate-to-vigorous intensity physical activity daily. Results from the Canadian Health Measures Survey found that only 9% of boys and 4% of girls accumulate 60 minutes of moderate-to-vigorous physical activity on at least 6 days a week (38): the majority of children therefore do not accumulate sufficient physical activity to maintain good health. Several factors may explain why children are physically inactive.

Participation in physical activity is influenced by various factors including biological and developmental factors, psychological factors, social and cultural factors, and physical environment factors (40). For example, boys are more likely to be active than girls, and differences in motor skills, body composition, and socialization may explain differences in physical activity between boys and girls (40). Psychological factors, such as self-efficacy, and knowledge, beliefs, and attitudes toward physical activity have also been found to be associated with physical activity in children and youth (40-41). Further, socioeconomic status is an important determinant of health behaviours including physical activity (40, 42). In addition, peer influences during adolescence and parent's physical activity levels also influence children's participation in physical activity (40). Finally, aspects of the physical environment such as the built environment, increased time spent on screen time (e.g., TV, computers, mobile phones), access to safe playgrounds and mode of transportation are all associated with children's participation in habitual physical activity (43-48).

Beyond these general individual, social and environmental factors, there is increasing interest in the impact of physical health, particularly physical disability, and emotional-behavioural problems as potential barriers to participation in physical activity in children. Indeed, although participation rates are low in the general Canadian children population (14-15), they are even lower in children with physical or emotional-behavioural problems (49-51). For example, Bandini and colleagues found that children with autism spectrum disorder participated in fewer types of physical activities and spend less time annually participating in these activities compared to typically developing children (49). Children with cerebral palsy are less likely to participate in structured and lower intensity physical activity compared to children without the condition (50-51). Children with poor motor coordination that is not attributable to cerebral palsy or other disorders of movement (e.g., muscular dystrophy) are another group that have been shown to be less physically active (29, 51-52). Overall, the available literature suggests that childhood physical disability is an important determinant of physical inactivity – a point that has been described in the literature as *the activity-deficit hypothesis*.

According to the *activity-deficit hypothesis*, children with movement difficulties, whether attributable to cerebral palsy, muscular dystrophy, or DCD, have lower levels of physical activity than their movement competent peers of similar social and cultural background (30, 52). In the specific case of DCD, the activity-deficit has been used in previous studies as a framework for exploring differences in physical activity and participation in active play. For example, Bouffard and colleagues (30) found that during recess, children with movement difficulties consistent with DCD engaged in significantly less physical activity on the playground and actively withdrew from participating in physical activity by not being on the playground and being out of sight of peers and teachers. Similarly, Thompson and colleagues (53) found that children with poor motor coordination (again consistent with DCD) avoided participating in physical education lessons. Studies examining the association between physical activity and motor coordination have found that children with DCD have poor physical fitness, and are less likely to participate in organized and free-play activities (13-24). A smaller body of work has also shown that participation in physical activity in this population tends to decline over time (17, 22).

Further, while this work emphasizes a deficit gap between typically developing children and those with DCD, the framework also describes a potential developmental process, attending to the issue of whether the deficit in activity participation remains constant over time or changes. Indeed, it has been suggested that the gap in activity-deficit in children with movement difficulties and their well-coordinated peers will widen over time (54). The *developmental skill-learning gap hypothesis,* an elaboration of the general activity-deficit hypothesis, proposes that as children get older, the difference in motor skill acquisition and proficiency between children with low or poor motor competence and their typically developing peers will grow larger (54). As children get older, those with typical development will be more motor proficient as they participate in more demanding and complex physical activities than children poor motor competence (54). In contrast, children with poor motor competence find it more difficult to participate in increasingly complex and rule-bound activities. As a result, they have reduced opportunities to practice their skills and will eventually withdraw from participating in physical activity altogether. To date, only three studies have directly explored whether differences in participation in active play widen over time between children with and without DCD. Two of these, one by Cairney and colleagues (55), the other by Bouffard and colleagues (30), compared organized and free play activities in children with DCD and typically developing children did not find evidence to support the developmental skill-learning gap hypothesis. An explanation for this finding may be that these studies were limited in that they had a small sample size and therefore a lower study power to detect significant differences between groups. Also, these studies were conducted using a cross-sectional study design and therefore it may be difficult to test for change in activity-deficit over time. A prospective examination of activity-deficit between children with and without DCD found that children with DCD consistently participated less in free-play and organized physical activities than typically developing children, and the gap in free-play activity between groups decreased over time for boys, but increased slightly over time for girls (21). However, the follow-up period of three years in this study maybe relatively short. Ideally, both the activity-deficit and learning-skill gap hypothesis should be tested using longitudinal data over a long developmental period.

The *learning-skill gap hypothesis* provides an explanation for the deficit in physical activity: Widening skill-gap may result in increases in physical inactivity in children with motor coordination problems. Therefore, the *learning-skill gap hypothesis* can be used to make predictions about the impact of DCD on children’s participation in physical activity over time.

**1.6 Body Composition and Developmental Coordination Disorder**

Among the many concerns associated with physical inactivity, increased risk of overweight and obesity is one of the most pressing. Estimates of childhood overweight and obesity are alarmingly high in Canada and the United States (80-83). Recent studies show prevalence in both countries to be between 25% and 33% (80-83). Due to their movement difficulties, children with DCD may avoid participating in physical activity and choose a more sedentary life style, and thus may be more likely to gain excess weight. Several cross-sectional studies have examined the effect of motor coordination on body composition measures including BMI, waist circumference, and body fat. Results showed that children with motor coordination difficulties have higher BMI (6, 15, 18, 23, 25, 27, 56-62), waist circumference (25, 58), and percent body fat (63-64) than typically developing children. In addition, two longitudinal studies have been conducted to examine changes in BMI and waist circumference in children with DCD over time. The findings of both these studies were conflicting. Cairney and colleagues found that children with DCD had higher BMI and waist circumference at baseline than children without DCD and this difference increased over the 2.5-year follow-up period (25). Conversely, the study by Hands did not find any significant difference in BMI between groups at baseline or over time (18).

The effect of gender on the relationship between poor motor coordination and body composition has been examined in a few cross-sectional studies and the results are inconsistent. Some studies found that boys with DCD have higher BMI and are more likely to be overweight or obese than girls (6, 16), while another study found no effect of gender (62). A longitudinal study that examined changes in BMI and waist circumference over time reported similar trends for boys and girls (25).

As discussed above, cross-sectional studies have examined the associations between DCD and body composition, and between DCD and physical activity. However, no study has examined the mediating effect of physical activity on the relationship between DCD and body composition. It is not known if differences in body composition between groups can be explained by differences in their physical activity levels. Therefore, one of the objectives of this study is to examine the effect of physical activity on the relationship between DCD and body composition.

Further, even by better understanding the effect of DCD on obesity over time, and the potential role of physical activity in explaining these associations, another notable gap in the literature concerns the potential combined impact of DCD and obesity on health and social outcomes in children. There is a growing literature on the negative impacts of poor motor coordination/motor competence on physical and mental health (12-13, 27-28, 31-32, 55, 84), and there is also an extensive literature linking overweight/obesity to mental and physical outcomes in children (75, 85-86). However, the combined effect of DCD and obesity on psychological outcomes such as global self-worth has not been examined previously.

### 1.7 Global Self-worth, Obesity, and Developmental Coordination Disorder

Excess weight gain and motor coordination problems are both associated with poor psychological outcomes such as low self-worth. Self-worth can be conceptualized as the overall evaluation of one's own worth or value as a person (87). Harter's Model of the Determinants of Self-worth identified two determinants of global self-worth: (1) the competence in domains of importance to children and youth including scholastic competence, social acceptance, athletic competence, physical appearance, and behavioural conduct and (2) the social support received from significant others (87). Harter's work found both these determinants to have an additive effect on global self-worth in children and adolescents. At each level of social support (low, moderate, and high) received in the form of approval from peers and parents, greater competence in domains of importance resulted in higher self-worth (88). Likewise, at each level of competence in domains of importance (low, moderate, and high), greater social support from classmates and parents resulted in higher self-worth (88). Therefore, it was proposed that individuals report the lowest self-worth if they perceive themselves to be incompetent in domains of importance and experience a lack of support, conversely, they report the highest self-worth if they perceive themselves to be highly competent in domains of importance and receive support from parents and peers. Harter also investigated which domains had the largest impact on children's self-worth. It was found that children's perceived competence in the domain of physical appearance made the largest contribution to the children's self-worth, followed by social acceptance, which was the second largest contributor to self-worth (87). Since children with DCD are more likely to be overweight/obese and experience social isolation, ridicule, and bullying, it would be of interest to examine the combined negative impact of both DCD and overweight/obesity on self-worth. Examining self-worth in children is also important because a child's level of self-worth has potential consequences on his or her health and everyday functioning. Children with low self-worth are more likely to experience body dissatisfaction, eating disorders, anxiety, loneliness, hopelessness, depression, suicidal behaviours, and engage in negative behaviours such as school absence, smoking, drinking, and drug use (65-67). Cross-sectional studies have examined the association between DCD and self-worth and the results are somewhat conflicting. Some studies have found lower self-worth score in children with DCD (68-70), while other studies did not find any association (32, 72-75).

Research has also shown that obese children are more likely to be dissatisfied with their body shape and size, experience social rejection and discrimination, and feel lonely and depressed, and therefore are more likely to report lower self-worth than their healthy weight peers (76). Given that the prevalence of overweight/obesity in children with DCD is high, 40 to 50% (25), it is important to examine if lower self-worth in children with DCD is related to their weight status. Indeed, conflicting results in the literature concerning DCD and self-worth may be due to failing to account for differences in overweight/obesity between groups. To date, no study has examined the combined effect of poor coordination and overweight/obesity on self-concept in children with DCD, either cross-sectionally or overtime.

### 1.8 Rationale and Study Objectives for this Dissertation

Although previous studies have examined the association between motor coordination and body composition, several gaps in the literature exist which are identified and addressed in this thesis. First, majority of the studies examining the effect of motor coordination on body composition have been cross-sectional and have, therefore, been unable to examine changes in body composition over time. The few longitudinal studies that have been conducted report inconsistent findings, have smaller sample sizes, and have a shorter follow-up period.

Second, the effect of gender on the relationship between motor coordination and body composition has been examined in cross-sectional studies and the results are conflicting. It is unclear if there is a difference in body composition measures between children with and without DCD over time, and if the trends are similar or different for boys and girls.

Third, the association between motor coordination and body composition, and between motor coordination and physical activity have only been examined independently. No longitudinal study has examined the effect of physical activity on the relationship between body composition and motor coordination. In other words, it is not known if differences in body composition measures between children with and without DCD can be explained by differences in their physical activity levels.

Fourth, many previous studies examining the association between motor coordination and body composition have used indirect measures of body fat such as BMI and waist circumference. There are limitations to using indirect measures such as BMI. BMI is a less sensitive measure of body fat because it does not accurately reflect changes in body fat and muscle mass. No longitudinal study has examined changes in percent body fat assessed directly using BOD POD. Likewise, studies examining the association between motor coordination and physical activity have used self-reported measure of physical activity. Self-report questionnaires are prone to recall bias and social desirability bias (77-79). Instead, direct measure of physical activity such as physical activity measured using an accelerometer and direct measure of body fat could be used when assessing the effect of physical activity on the association between motor coordination and body composition.

Finally, studies have examined the association between motor coordination and global self-worth, and between weight status and global self-worth. Results showed that children with motor coordination difficulties report lower self-worth, and overweight and obese children also report lower self-worth. However, the secondary consequences of being overweight/obese in children with DCD have not been examined. It is not known whether children with DCD who are also overweight or obese experience further disadvantage and report an even lower self-perception of worth than children who experience each condition independently. In addition, the effect of age on the association among DCD, obesity, and self-worth also needs to be examined.

Therefore, the purpose of this thesis is to conduct a series of studies that examine the relationship among DCD, body composition, physical activity, and global self-worth in children, while carefully addressing the limitations of previous studies identified in the literature. The specific objectives of each study are listed below.

Study 1 (Chapter 2)

1) Are children with DCD more likely than their typically developing peers to have higher BMI and waist circumference at baseline?

2) Do differences in BMI and waist circumference between children with DCD and typically developing children decrease, increase, or remain constant over time as children age?
3) Does sex moderate the association between DCD and BMI, and between DCD and waist circumference over time?
4) Does physical activity moderate the association between DCD and BMI, and between DCD and waist circumference?

Study 2 (Chapter 3)

1) Do differences in percent body fat and BMI between children with DCD and those without vary or remain constant over time as children get older?
2) Does the relationship between DCD and body composition measures over time differ by sex?
3) Does engaging in moderate-to-vigorous level physical activity have any effect on the relationship between DCD and body composition measures?

Study 3 (Chapter 4)

1) Is there a relationship between global self-worth and DCD and overweight/obese statuses at baseline after adjusting for age, sex, and overweight/obesity status at later time points?
2) What influence does aging (time) have on the association among DCD, relative body weight and self-worth? Does sex influence the association among DCD, relative body weight and self-worth?

Together, this body of work will increase our overall understanding of the consequences of DCD in relation to the intersections among physical activity, overweight/obesity, and self-worth in boys and girls with the disorder. Understanding the pathways and identifying the factors related with overweight/obesity and lower self-worth is also important so that intervention programs can be designed to address these problems and lower the risk of health conditions associated with obesity and poor self-worth.

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# CHAPTER 2

Divya Joshi, Cheryl Missiuna, Steven Hanna, John Hay, Brent E. Faught, John Cairney. (2015). Relationship between BMI, waist circumference, physical activity and probable developmental coordination disorder over time. *Human Movement Science*, 40, 237-247.

**Relationship between BMI, waist circumference, physical activity and probable developmental coordination disorder over time**

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**Abstract**

**Background:** Cross-sectional studies have shown that children with developmental coordination disorder (DCD) are less likely to be physically active and have excess weight gain. However, longitudinal studies examining the relationship between DCD and measures of body composition (BMI and waist circumference) over time are lacking. It is not known if sex and physical activity affect the relationship between DCD and measures of body composition over time.

**Objectives:** 1) To examine if BMI and waist circumference in children with and without probable DCD (pDCD) remain constant over time or change as children age, and whether this relationship varies by sex. 2) To examine if differences in physical activity between children with and without pDCD account for differences in BMI and waist circumference over time.

**Methods:** Physical Health Activity Study Team (PHAST) data were used for this longitudinal analysis. At baseline, a total of 2,278 (pDCD=103) children aged 8-10 years were included in the analysis. The total follow-up period was five years. Mixed-effects modelling was used to estimate change in body composition measures in children over time.

**Results:** Children with pDCD have higher BMI and waist circumference compared to typically developing children, and this difference increased over the study period. The relationship between pDCD and BMI over time also varies by sex. A similar trend was observed for waist circumference. Boys with pDCD were found to have a more rapid increase in BMI and waist circumference compared to girls with pDCD. Physical activity had neither a mediating nor a moderating effect on the relationship between pDCD and measures of body composition. However, physical activity was independently and negatively associated with measures of body composition.

**Conclusions:** pDCD is associated with higher body mass and waist circumference, both important risk factors for cardiovascular disease, type 2 diabetes, and psychological problems and other health conditions.

**Keywords:** Developmental Coordination Disorder, BMI, Waist Circumference, Physical Activity, Children

## 2.1 Introduction

Developmental coordination disorder (DCD) is a neurodevelopmental disorder affecting motor coordination, which negatively impacts activities of daily living and scholastic achievement (American Psychiatric Association [APA], 2013). The prevalence of DCD is between 1.8% and 6% (Cairney, Hay, Faught, & Hawes, 2005a; Gibbs, Appleton, & Appleton, 2007; Lingam, Hunt, Golding, Jongmans, & Emond, 2009). Despite the relatively high prevalence of this condition, it is often not diagnosed in children (Missiuna et al., 2008).

As a result of poor motor coordination, children with DCD often face embarrassment and ridicule from their peers, and are less likely to participate in active physical free play and in organized sport and physical activities (Cairney et al., 2005b; Cairney et al., 2007; Hands, 2008; Schott, Alof, Hultsch, & Meermann, 2007). This is troubling, given the many positive social, physical, and mental effects associated with being physically active (Strong et al., 2005). Physical inactivity has also been identified as one of the core risk factors associated with the pediatric obesity epidemic in North America, and in other parts of the developed world (Janssen et al., 2005).

Simply recommending increased levels of physical activity in children with DCD is likely to be ineffective as they do not have sufficiently proficient fundamental motor skills needed to participate in these activities or to engage in active play. Bar-Or (1983) described an activity deficit hypothesis which posits that children with movement difficulties are less physically active compared with their movement-competent peers. Previous studies support the activity deficit hypothesis in children with poor motor coordination (Beutum, Codier, & Bundy, 2012; Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996; Cairney et al., 2005b; Cantell, Crawford, & Doyle-Baker, 2008; Poulsen, 2008; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006).

Over time, reduced physical activity leads to an increased risk of overweight/obesity (Hands & Larkin, 2002). Therefore, it has been hypothesized that physical inactivity in children with DCD places them at higher risk for unhealthy weight gain (Cairney et al., 2005a; Cairney & Veldhuizen, 2013). According to a recent systematic review, 13 of 18 studies examining the relationship between motor proficiency and body composition found that children with poor motor proficiency had significantly higher BMI, waist circumference, and percent body fat compared to their peers (Rivilis et al., 2011). Longitudinal research has also shown poor motor coordination to predict negative changes in body weight, including increased risk of overweight and obesity (Cairney et al., 2010b; Osika & Montgomery, 2008).

Although previous research has examined the relationship between DCD and excess body weight, there are several gaps in the literature which are addressed in the current study. First, few studies have examined body composition (including overweight and obesity) in children with DCD and among these, most have used cross-sectional designs (Cairney & Veldhuizen, 2013). Large, population-based longitudinal studies examining the association between DCD, and measures of body composition over time are lacking. Moreover, the few longitudinal studies that have been conducted report conflicting findings (Cairney et al., 2010b; Hands, 2008) or have a short follow-up period (Cairney et al., 2010b). The relationship between DCD and measures of body composition needs to be examined over an extended period of time as the effect of inactivity is insidious and cumulative.

Second, the effect of sex on the relationship between motor coordination and body composition has been examined in only a small number of cross-sectional studies and the results are discrepant (Cairney et al., 2005a; Schott et al., 2007; Wrotniak et al., 2006). After reviewing literature in this area, it is unclear whether the relationship between DCD and measures of body composition differs by sex. This study addresses this gap by testing for the effect of sex on the relationship between DCD and measures of body composition over a five-year period.

Third, cross-sectional studies have examined the association between DCD and measures of body composition, and DCD and physical inactivity independently (Cairney et al., 2005a; Schott et al., 2007; Wrotniak et al., 2006). However, to our knowledge, no study has examined whether the differences in measures of body composition in children with and without DCD are related to differences in physical activity.

The aforementioned limitations in the extant literature can be addressed by examining a large group of children with and without poor motor coordination, and repeatedly tracking multiple measures of body composition (e.g., BMI and waist circumference), and physical activity over time. While ideally, it would be desirable to examine the long-term consequences of DCD in relation to overweight/obesity, from childhood through to middle and old age, such data do not currently exist. At the same time, understanding the temporal associations among motor coordination, physical activity, and body composition during key developmental periods can still make significant contributions to our understanding of these associations. One such period is the transition between middle childhood and adolescence. Developmentally, this period is associated with rapid and often dramatic changes in physical, maturational, social, and psychological domains (Sun et al., 2002; Yurgelun-Todd, 2007). For example, differences in rate of growth (Sun et al., 2002), changes in body size and composition (Wang, 2002), changes in physical activity patterns as well as differences in physical activity levels between boys and girls are well documented during this period (Kimm et al., 2005; Sherar, Esliger, Baxter-Jones, & Tremblay, 2007; Telama & Yang, 2000). Moreover, previous studies have shown both physical activity and overweight/obesity during this period to be predictive of physical activity (Telema, Yang, Laakso, & Viikari, 1997; Telama et al., 2005) and body composition later in adulthood (Guo, Wu, Chumlea, & Roche, 2002; Whitaker, Wright, Pepe, Seidel, & Dietz, 1997).

In the present study, we are able to examine the prospective associations among poor motor coordination, physical activity and body composition using a large cohort of children as they age from 9 to 14 years of age. The following research questions are examined: (1) Are children with DCD more likely than their typically developing peers to have higher BMI and waist circumference at baseline? (2) Do differences in BMI and waist circumference between children with DCD and those without decrease, increase, or remain constant over time as children age? (3) Does sex moderate the association between DCD and BMI, and between DCD and waist circumference over time? (4) Does physical activity moderate the association between DCD and BMI, and between DCD and waist circumference?

## 2.2 Methodology

### *2.2.1 Study Participants*

The Physical Health Activity Study Team (PHAST) project is a longitudinal cohort study of children's physical activity, anthropometry, and aerobic fitness that began in the spring of 2005. The study population involved all children in the fourth grade (ages 8 to 10 years) who were enrolled in the public school system in the Niagara region of Ontario, Canada. Permission to enrol students was obtained from 75 of 92 (83%) schools. At baseline, informed consent was obtained from parents of 2278 of 2378 (95.8%) children. The first wave of data was collected in the spring of 2005 with reassessments conducted in the fall of 2005 (wave 2), spring and fall of 2006 (wave 3 and wave 4), spring and fall of 2007 (wave 5 and wave 6), fall of 2008 (wave 7), and fall of 2009 (wave 8). The total follow-up period was approximately five years. Ethics approval for the study was obtained from the district school board and Brock University. A total of 2,278 children who were available at baseline are included in the analysis. The flow of participants in the PHAST I study is presented in Appendix I, and the retention of participants over multiple waves is presented in Appendix II.

### *2.2.2 Measurement of Study Variables*

#### *2.2.2.1 Assessment of Motor Coordination*

Motor coordination was assessed using the short form of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP-SF) (Bruininks, 1978). The BOTMP-SF examined all components of motor coordination using selected items from the full scale. The short form has been validated against the full scale and correlations between 0.90 and 0.91 have been reported for children aged 8 to 14 years (Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2010a). The test takes about 20 minutes to complete and was administered individually to each child in a school's gymnasium by a trained research assistant. All reasonable attempts were made to ensure privacy during testing to minimize distractions and make the child feel comfortable. Children who scored below the $6^{th}$ percentile on the BOTMP-SF were considered to be "probable" cases of DCD (pDCD), given that testing was conducted by research assistants and no formal diagnosis was made by a physician. Criterion B of the DSM-IV (APA, 2013) was not specifically assessed in this study; however, all participants with known intellectual or physical disabilities were excluded. The validity of this field-based assessment has been published previously (Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2009). The results showed that 88% of children scoring below the $6^{th}$ percentile on the BOTMP-SF met the motor impairment criteria for DCD based on the $15^{th}$ percentile of the Movement Assessment Battery for Children (Cairney et al., 2009).

*2.2.2.2 Body Composition*

Height was measured using a stadiometer and was recorded to the nearest 0.2 cm. Weight was measured using an electronic weight scale and was recorded to the nearest 0.1 kg. Height and weight measurements were obtained without footwear and children wore light clothing suitable for physical education class (e.g., t-shirt and shorts). BMI ($kg/m^2$) was calculated by dividing weight in kilograms over height in metre squared. Waist circumference was measured midway between the lowest rib and the superior border of the iliac crest (Gillum, 1999). Waist circumference measures were obtained two times and the average of these readings was used in the analyses.

2.2.2.3 *Physical Activity*

The Participation Questionnaire is a 63-item self-reported questionnaire (Appendix III). Children were asked to report their participation in free-time play, intramurals, school and community sport teams, and other organized activities over a one year period (Hay, 1992). Children were also asked to report their participation in free-time play based on typical past-time activities they performed shortly before the time of completion of the questionnaire. The free-time play component has eight items and scores ranged from 0 to 20. The organized activities component has six items and scores ranged from 0 to 29. Therefore, total physical activity scores ranged from 0 to 49, with higher scores indicating greater physical activity. The Participation Questionnaire has shown reasonable evidence of construct validity: previous studies have reported significant differences between boys and girls, those living in urban and rural settings, and significant correlations with body fat and aerobic capacity (Cairney et al., 2010a; Hay, 1992). The Participation Questionnaire has also been shown to correlate with the teacher's assessment of physical activity in children (r=0.62) (Cairney et al., 2010a; Hay, 1992). The test-retest reliability is reported to be 0.81 over a period of two weeks (Hay, 1992).

*2.2.3 Statistical Analyses*

Student's *t* test was used to compare baseline differences in BMI, waist circumference, and physical activity between groups (with and without pDCD). The dependent variables (BMI and waist circumference) were used as a continuous measure because dichotomization does not make use of within-category information and everyone within the “healthy body weight” and “overweight/obese” categories would otherwise be treated the same, even though they may vary considerably.

Mixed effects models were used to examine the relationship between sex, pDCD, and measures of body composition in children. Time (months) since baseline was modelled as a linear variable to see if the difference between groups increased exponentially or remained monotonic over time. Time was also modelled as a non-linear variable (quadratic term). The quadratic term for time was significant for waist circumference but not significant for BMI. The coefficient for the quadratic time variable was small for BMI ($1.9 \times 10^{-5}$) and waist circumference ($-1.2 \times 10^{-3}$), and hence was excluded from the analyses in order to build a parsimonious regression model. Random intercept at the participant level and random slope for time were included in the analysis. To determine if the change in BMI and waist circumference varies by pDCD status, a time by pDCD interaction term was tested. To examine if this relationship is influenced by sex, three-way interaction term between sex, pDCD, and time was tested. Finally, to determine if change in BMI and waist circumference varies by physical activity levels, three-way interaction term between physical activity, pDCD, and time was tested.

## 2.3 Results

In this sample, 103 children (4.5%) met the criteria for probable DCD (pDCD). Descriptive characteristics of the participants at each wave of the study are provided in Table 1. At baseline, children with pDCD had approximately 15% higher mean BMI scores ($t = 14.73$, $p = <.0001$), 12% higher mean waist circumference ($t = 15.72$, $p = <.0001$), and 26% lower total physical activity scores ($t = -19.01$, $p = <.0001$) than typically developing children.

The results from the mixed-effects models predicting BMI and waist circumference from age at baseline, sex, pDCD, and time are presented in Tables 2 and 3, respectively. For both BMI and waist circumference, there were significant main effects for time. Compared with typically developing children, children with pDCD had higher BMI (average difference of 2.5 $kg/m^2$) and higher waist circumference (average difference of 7.6 cm). For BMI and waist circumference, interaction terms between time and pDCD status were tested in model 1. The two-way interaction term between time and pDCD status was significant for BMI and waist circumference. This positive effect indicates that the differences in BMI and waist circumference between children with pDCD and those without are increasing over time. For both BMI and waist circumference, there was no evidence of two-way interaction between pDCD status and sex (model 2). The three-way interaction between time, pDCD status, and sex was significant for BMI but not statistically significant for waist circumference (p-value: 0.0577). This indicates that the influence of pDCD on change in BMI differs over time by sex. Although the three-way interaction between time, pDCD, and sex was not statistically significant for waist circumference, the regression equation was graphed to view the trend. The regression equations from model 3 were graphed in order to interpret this relationship (Figures 1 and 2). It can be seen that pDCD was associated with increases in BMI over time and a similar trend was observed for waist circumference.

Specifically, boys with pDCD showed a more rapid increase in BMI and waist circumference over time compared to girls with pDCD. The trajectories were similar for boys and girls without pDCD.

The effect of physical activity on the relationship between BMI and pDCD status, and waist circumference and pDCD status were also examined (results not reported). A significant negative relationship was found between BMI and total physical activity score, and between waist circumference and total physical activity score. After adjusting for total physical activity, there was no change in the magnitude of the regression coefficient for the three-way interaction term between time, pDCD status, and sex for both BMI and waist circumference. This suggests that physical activity does not mediate the relationship between BMI and pDCD status, and waist circumference and pDCD status. Two-way interaction between time and physical activity was significant for BMI only, suggesting that BMI scores decrease with increase in physical activity over time. For both BMI and waist circumference, the three-way interaction between time, pDCD status, and physical activity was not significant. This suggests physical activity does not moderate the relationship between BMI and pDCD status, and between waist circumference and pDCD status over time.

## 2.4 Discussion

Results from this study demonstrate that children with pDCD have higher BMI and waist circumference compared to typically developing children and that this difference increased over the five-year follow-up. The relationship between pDCD and

BMI over time varied by sex, and although a similar trend was observed for waist circumference, it was not statistically significant (p=0.0577). Boys with pDCD were found to have a greater increase in BMI and waist circumference over time compared to girls with pDCD. Physical activity did not have a mediating or a moderating effect on the relationship between pDCD status and BMI, or on pDCD status and waist circumference. However, it was independently and negatively associated with BMI and waist circumference.

Our findings with regard to pDCD, time, BMI and waist circumference are consistent with some previous research which found that children with DCD had higher BMI and waist circumference scores at baseline and that these differences increased slightly over time (Cairney et al., 2010b; Zhu, Wu, & Cairney, 2011). In contrast, a 5-year follow-up study conducted with 5 to 7 year olds found no significant difference in BMI between groups of children with low motor competence and high motor competence at baseline or over time (Hands, 2008). However, this study by Hands (2008) had a small sample of only 38 participants and the difference in the age range sampled may explain this contradictory finding. It is important to note however, that each of the aforementioned studies used three different measures of motor coordination: M-ABC (Zhu, Wu, & Cairney, 2011), BOT-SF (Cairney et al., 2010b), and the sprint run, standing board jump, and balance (Hand, 2008). While the results of our study confirm those found by Zhu and colleagues (2008) and Cairney and colleagues (2010b), we cannot rule out entirely the possibility that differences in measurement may explain inconsistency in findings between our results and those of Hands (2008).

This is the first study to find a significant three-way interaction between pDCD status, sex, and time for BMI and a trend toward statistical significance for waist circumference. Interestingly an earlier study by Cairney and colleagues (2010b), using the same cohort, did not find a significant three-way interaction between pDCD, sex, and time. We believe this is due to fact that the study was based only on the first two years of data collected with this cohort. Unlike the first study, our data covered a five-year time period, tracking children over a longer developmental period (from age 9 to 14 years). This suggests that the effect of sex on time for DCD occurs later in childhood. From Figures 1 and 2 it can be estimated that boys with pDCD have a rapid increase in BMI and waist circumference at approximately 11 years of age which may coincide with maturational changes. The rapid changes in physical growth and maturation, and the accompanying social and psychological maturational changes that occur in the transition from middle childhood to adolescence, account at least in part for why these complex association among sex, pDCD and body composition are found. Girls, for example, attain peak growth velocity and sexual maturation at an earlier age than boys (Rogol, Clark, & Roemmich, 2000). Growth spurts and onset of puberty is known to be associated with changes in body size and composition (Wang, 2002). During preadolescence, the percentages of body fat and lean body mass are similar between boys and girls (Wang, 2002). However, during adolescence, girls experience a relatively greater increase in fat mass than lean body mass, whereas boys gain more lean body mass than fat mass (Wang, 2002). Early onset of sexual maturity may affect body composition through its influence on growth (height and weight) in boys and girls. For example, Wang (2002) found boys who matured earlier were taller, although their body weight was similar from boys who did not mature earlier, resulting in lower BMI scores. It is interesting to speculate that differences in rate of maturation between children with and without DCD may account for some of the effect of motor coordination on body composition during this developmental period. Further research exploring these effects is required.

Our study also found that while physical activity was an independent predictor of BMI and waist circumference, it did not mediate the relationship between pDCD status and either BMI or waist circumference. In other words, differences in physical activity scores do not explain why children with pDCD have higher BMI and waist circumference. Moreover, physical activity does not seem to explain the sex differences within the pDCD group as both boys and girls displayed similar physical activity patterns over time. These results, therefore, do not support the activity deficit hypothesis which suggests that children with movement difficulties are less physically active compared to children without movement difficulties (Bar-Or, 1983). While intriguing, caution regarding over-interpretation of this finding is warranted, given data and measurement limitations. For example, one explanation for this finding is that the measure of physical activity in this study was not a direct measure of energy expenditure. Although self-reports are useful for gaining insight into physical activity levels, they are limited in terms of reliability and validity (Prince et al., 2008). Assessing physical activity levels through self-reports can overestimate or underestimate the true energy expenditure due to physical activity. Self-reported physical activity is also prone to recall and social desirability biases. Another explanation may be that because children generally are physically inactive (91% of boys and 96% of girls) and do not meet the Canadian recommendations for physical activity (Colley et al., 2011), the actual difference in physical activity between children with and without pDCD may be much smaller than would be predicted by the activity-deficit hypothesis. Therefore, inactivity differences may be relatively less important to understanding the differences in measures of body composition between groups. Another study found that children with DCD participated in significantly less moderate-to-vigorous physical activity than children without DCD and found strength, type of activity, and family factors such as parents' activity participation to be associated with participation in moderate-to-vigorous activity in children with DCD (Beutum, Cordier, & Bundy, 2012). Examining these types of factors may provide insight into the physical activity patterns in children with pDCD and may explain the higher BMI and waist circumference in this group. Finally, it is possible that significant differences in nutritional intake between children with and without pDCD may explain the higher BMI and waist circumference scores in children with pDCD. The effect of nutritional intake on the relationship between pDCD and BMI, and between pDCD and waist circumference should be examined in future studies. We know of no research that has shown differences in dietary behaviors between these groups.

The strengths of the current study include use of a longitudinal study design that allowed the exploration of trajectories of change in relative weight over time in the same cohort of children with and without pDCD. Further, we were able to explore the unique and multiplicative contributions of both sex and physical activity on these changes in body composition over time. Examining BMI and waist circumference from 9 to 14 years is important because it allows us to examine body composition during a period when significant metabolic changes and changes in growth and maturation are taking place, thus providing information regarding current and future health status of the child. This study recruited a population-based sample thereby reducing concerns related to clinical-referral bias. Finally, this study had a large sample size, which ensured adequate power to examine the research questions.

Several limitations of this study need to be addressed in future work. First, pDCD cases were identified by research assistants using a screening instrument and this identification was not confirmed by a physician. Second, DSM-IV diagnostic criterion B was not addressed when identifying children with pDCD which may have led to an overestimation of the number of pDCD cases. Third, participation in physical activity was self-reported and social-desirability bias or recall bias may have occurred. Finally, BMI and waist circumference scores were used as proxy measures for body fat. Future studies should consider using direct measures of energy expenditure and body fat.

## 2.5 Conclusions

The findings of this study showed that children with pDCD had higher BMI and waist circumference than typically developing children and that this difference increased slightly over the study period. Among the pDCD group, this relationship differed by sex with boys having a more rapid increase in BMI compared to girls. Similar trends were also observed for waist circumference. Physical activity was an independent predictor of BMI and waist circumference. These results suggest that DCD is associated with higher body mass and waist circumference which are important risk factors for cardiovascular disease, type 2 diabetes, and psychological problems among other health conditions. Physical activity did not explain the differences in measures of body composition between groups suggesting that inactivity differences may be relatively less important to understanding the differences between measures of body composition between groups. Future studies should consider examining other factors that may affect this relationship and that can be targeted for intervention purposes. Future studies using more sensitive measures of body fat and energy expenditure are also required.

**Table 1: Descriptive characteristics of the participants at each wave**

| | **Wave 1** | **Wave 2** | **Wave 3** | **Wave 4** | **Wave 5** | **Wave 6** | **Wave 7** | **Wave 8** |
|---|---|---|---|---|---|---|---|---|
| **n** | 2278 | 2228 | 2273 | 2134 | 2141 | 1896 | 1805 | 1581 |
| **Age (yrs), mean (SD)** | 9.9 (0.4) | 10.3 (0.4) | 10.9 (0.3) | 11.3 (0.3) | 11.9 (0.3) | 12.4 (0.3) | 13.4 (0.3) | 14.6 (0.4) |
| **Sex, n (%)** | | | | | | | | |
| **Male** | 1158 (50.8) | 1076 (50.6) | 1083 (51.0) | 1060 (50.5) | 1037 (50.1) | 937 (50.7) | 885 (50.6) | 703 (50.5) |
| **Female** | 1120 (49.2) | 1051 (49.4) | 1042 (49.0) | 1038 (49.5) | 1032 (49.9) | 912 (49.3) | 864 (49.4) | 688 (49.5) |
| **pDCD, n (%)** | 103 (4.5) | 102 (4.6) | 104 (4.6) | 98 (4.6) | 97 (4.5) | 58 (3.1) | 60 (3.3) | 48 (3.0) |
| **BMI (kg/m$^2$), mean (SD)** | | | | | | | | |
| **pDCD** | 21.1 (5.1) | 22.0 (5.1) | 22.4 (5.5) | 22.7 (5.5) | 23.2 (5.6) | 24.6 (5.9) | 25.6 (6.3) | 25.7 (6.3) |
| **No pDCD** | 18.4 (3.4) | 18.8 (3.5) | 19.1 (3.6) | 19.5 (3.9) | 19.9 (3.9) | 20.2 (3.9) | 21.0 (4.0) | 21.5 (4.0) |
| **Male** | 18.5 (3.5) | 18.9 (3.7) | 19.2 (3.7) | 19.6 (3.9) | 20.0 (4.0) | 20.4 (4.1) | 21.0 (4.2) | 21.5 (4.2) |
| **Female** | 18.6 (3.6) | 19.0 (3.7) | 19.2 (3.8) | 19.8 (4.1) | 20.2 (4.1) | 20.3 (4.0) | 21.3 (4.2) | 21.7 (4.1) |
| **All** | 18.6 (3.5) | 19.0 (3.7) | 19.2 (3.8) | 19.7 (4.0) | 20.1 (4.0) | 20.3 (4.1) | 21.2 (4.2) | 21.6 (4.2) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Waist circumference (cm), mean (SD)** | | | | | | | | |
| **pDCD** | 72.2 (13.6) | 76.0 (13.5) | 78.4 (13.7) | 79.6 (14.5) | 81.3 (14.8) | 83.1 (14.2) | 84.8 (15.9) | 86.3 (15.9) |
| **No pDCD** | 64.7 (9.7) | 67.0 (10.1) | 68.6 (10.1) | 70.1 (10.9) | 71.3 (10.9) | 71.3 (10.7) | 74.0 (11.4) | 76.4 (10.7) |
| **Male** | 64.9 (10.0) | 67.4 (10.3) | 69.0 (10.5) | 70.3 (11.2) | 71.7 (11.4) | 72.2 (11.3) | 74.4 (12.0) | 76.9 (11.5) |
| **Female** | 65.1 (10.1) | 67.5 (10.6) | 69.3 (10.4) | 70.9 (11.3) | 71.8 (11.3) | 71.1 (10.7) | 74.2 (11.4) | 76.5 (10.6) |
| **All** | 65.0 (10.1) | 67.4 (10.4) | 69.1 (10.5) | 70.6 (11.3) | 71.7 (11.3) | 71.6 (11.0) | 74.3 (11.7) | 76.7 (11.1) |
| **Total physical activity score, mean (SD)** | | | | | | | | |
| **pDCD** | 11.6 (6.3) | 10.6 (5.2) | 11.9 (5.3) | 10.4 (4.8) | 12.4 (5.8) | 11.6 (5.3) | 10.2 (4.5) | --- |
| **No pDCD** | 15.6 (6.7) | 15.1 (6.8) | 17.1 (7.2) | 14.9 (6.4) | 17.4 (7.0) | 15.1 (6.4) | 13.8 (5.9) | --- |
| **Male** | 15.5 (7.0) | 14.9 (6.8) | 16.8 (7.4) | 14.9 (6.5) | 17.4 (7.4) | 15.2 (6.5) | 14.3 (6.1) | --- |
| **Female** | 15.2 (6.5) | 14.8 (6.6) | 17.0 (6.9) | 14.6 (6.4) | 16.9 (6.7) | 14.8 (6.3) | 13.1 (5.6) | --- |
| **All** | 15.4 (6.8) | 14.9 (6.7) | 16.9 (7.2) | 14.7 (6.4) | 17.2 (7.0) | 15.0 (6.4) | 13.7 (5.9) | --- |

**Table 2: Mixed-effects models predicting BMI by age at baseline, sex, probable developmental coordination disorder, and time**

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | **Estimate** | **p-value** | **Estimate** | **p-value** | **Estimate** | **p-value** |
| **Intercept** | 18.23 | <.0001 | 18.22 | <.0001 | 18.24 | <.0001 |
| **Age at baseline (yrs)** | 0.38 | 0.0619 | 0.38 | 0.0650 | 0.38 | 0.0648 |
| **Time (months)** | 0.07 | <.0001 | 0.07 | <.0001 | 0.06 | <.0001 |
| **Sex (Female)** | $9.5 \times 10^{-4}$ | 0.9946 | 0.03 | 0.8527 | $-6.6 \times 10^{-3}$ | 0.9634 |
| **pDCD** | 2.53 | <.0001 | 3.03 | <.0001 | 2.87 | <.0001 |
| **Time*pDCD** | 0.02 | <.0001 | | | 0.04 | 0.0257 |
| **Sex*pDCD** | | | -0.69 | 0.3480 | -0.58 | 0.4309 |
| **Time*Sex** | | | | | $8.8 \times 10^{-3}$ | <.0001 |
| **Time*pDCD*Sex** | | | | | -0.03 | 0.0127 |

**Table 3: Mixed-effects models predicting waist circumference by age at baseline, sex, probable developmental coordination disorder, and time**

| | **Model 1** | | **Model 2** | | **Model 3** | |
|---|---|---|---|---|---|---|
| | **Estimate** | **p-value** | **Estimate** | **p-value** | **Estimate** | **p-value** |
| **Intercept** | 64.88 | <.0001 | 64.85 | <.0001 | 64.87 | <.0001 |
| **Age at baseline (yrs)** | 1.35 | 0.0182 | 1.34 | 0.0192 | 1.34 | 0.0191 |
| **Time (months)** | 0.22 | <.0001 | 0.23 | <.0001 | 0.22 | <.0001 |
| **Sex (Female)** | -0.22 | 0.5676 | -0.15 | 0.7031 | -0.16 | 0.6906 |
| **pDCD** | 7.55 | <.0001 | 8.94 | <.0001 | 8.39 | <.0001 |
| **Time*pDCD** | 0.04 | 0.0182 | | | 0.08 | 0.0031 |
| **Sex*pDCD** | | | -1.91 | 0.3525 | -1.46 | 0.4805 |
| **Time*Sex** | | | | | $1.3 \times 10^{-3}$ | 0.8573 |
| **Time*pDCD*Sex** | | | | | -0.07 | 0.0577 |

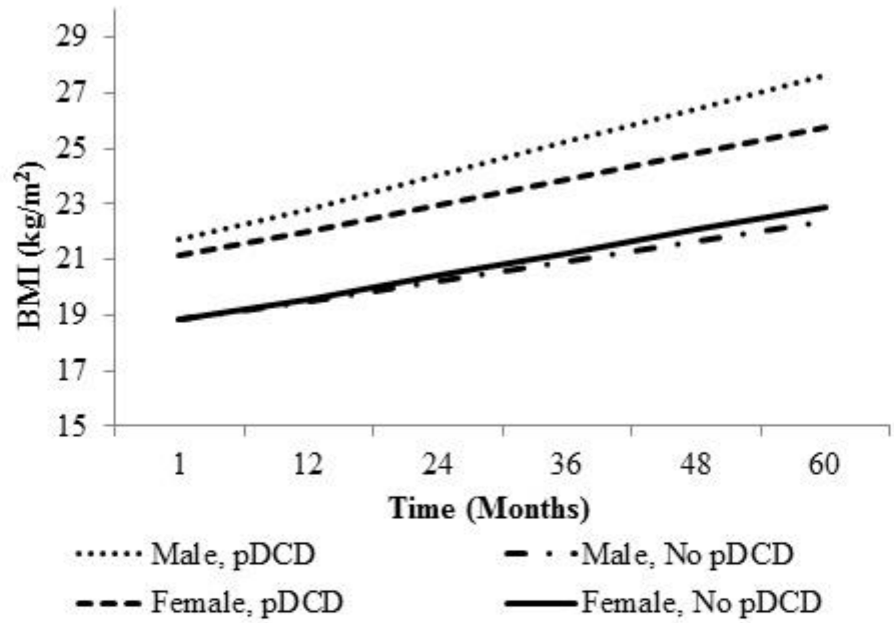


**Figure 1: Predicted BMI among boys and girls with and without probable developmental coordination disorder (pDCD)**

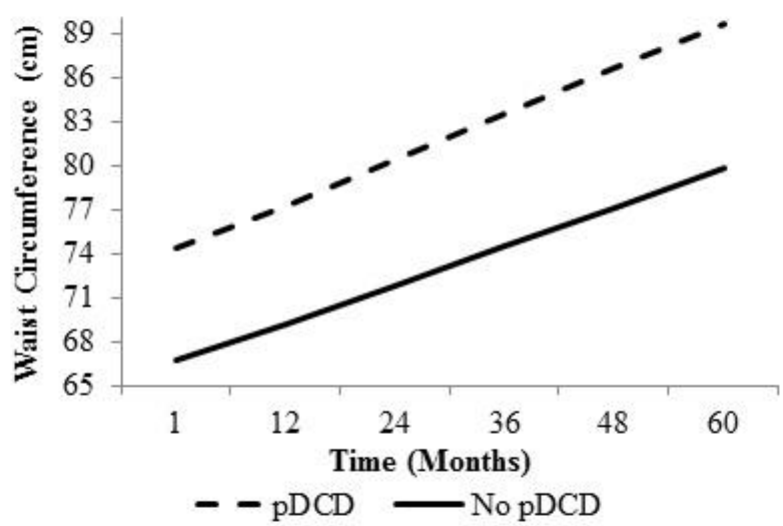


**Figure 2: Predicted waist circumference among boys and girls with and without probable developmental coordination disorder (pDCD)**

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# CHAPTER 3

Divya Joshi, Cheryl Missiuna, Steven Hanna, John Hay, Brent E. Faught, John Cairney. Relationship among percent body fat, developmental coordination disorder, and energy expenditure over time (Submitted to *Medicine and Science in Sports and Exercise*, May 24, 2015).

**Relationship among percent body fat, developmental coordination disorder, and energy expenditure over time**

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**Abstract**

**Background:** Most previous studies examining the association between developmental coordination disorder (DCD) and body composition have used BMI as a proxy measure for body fat and physical activity, and have not obtained repeated assessments for motor coordination. The purpose of this study is to examine the relationship between probable DCD (pDCD) and percent body fat and BMI in children over time using a direct measure for body fat and physical activity.

**Methods:** A subset of children from the Physical Health Activity Study Team (PHAST) project was used for this longitudinal analysis. A total of 126 (pDCD=60) children aged 12-13 years were included in the analysis. Mixed-effects modelling was used to estimate change in percent body fat and BMI over time adjusted for age at baseline, sex, annual household income, and birth weight.

**Results:** In comparison to typically developing children, children with pDCD have higher body fat and BMI at baseline, and the difference between groups increase over time for BMI, while it remains constant over time for percent body fat. Participation in moderate-to-vigorous physical activity has a minimal effect on the relationship between pDCD and percent body fat, and between pDCD and BMI.

**Conclusions:** Increased BMI and body fat in children with pDCD is a concern because both these factors are associated with increased risk of cardio-metabolic abnormalities and poor psychosocial outcomes.

**Keywords:** Developmental Coordination Disorder, BMI, Percent Body Fat, Accelerometer, Children

### 3.1 Introduction

Developmental coordination disorder (DCD) is a neurodevelopmental condition resulting in impairment of motor coordination that is not related with any other medical condition, and which negatively affects children's academic achievement and everyday functioning (2). This condition affects 1.8% to 6% of children (10, 24, 35).

Owing to difficulties in motor coordination, children with DCD have been found to be less physically active when compared with their typically developing peers (7, 11, 16). As a result, there is concern that children with DCD may be deprived of the positive benefits associated with physical activity. For example, physical activity is known to have beneficial effects on bone and skeletal health, cardiovascular health (body weight, lipid profile, adiposity, blood pressure, and insulin resistance), psychosocial health (self-concept, motor development, cognitive development, anxiety, depression symptoms, and social functioning), and academic performance (52). Although regular physical activity is associated with many physiological and psychological benefits, recent findings have shown that children spend less time in moderate or vigorous physical activity and spent most of their time in sedentary activities (18, 19, 54). This general trend may be further exacerbated in children with DCD (7, 9, 11, 16, 17, 27).

According to the activity deficit hypothesis proposed by Bar-Or, children with movement difficulties are less likely to be physically active and more likely to be sedentary compared to children without movement difficulties (4). Results of studies examining physical activity in children with DCD have found support for the activity deficit hypothesis. Children with DCD are more likely to engage in sedentary activities, use playground equipment less often, spend time alone on the playground, have lower perceived adequacy for physical activity, and engage in fewer organized and unorganized physical activities compared to their typically developing peers (7, 9, 11, 16, 17, 27).

Over time, physical inactivity is associated with unhealthy weight gain. Since children with DCD are less likely to be physically active, they are also at an increased risk of obesity and related health conditions. Several studies examining the relationship between measures of body composition and DCD have reported that children with DCD have a higher BMI, waist circumference, and body fat compared to typically developing children (10, 14, 17, 23, 26, 28, 48, 56, 59). A 5-year longitudinal study examining the relationship among measures of body composition, DCD, and physical activity found that children with DCD had higher BMI and waist circumference than typically developing children and this difference increased over time (30). The increase in BMI and waist circumference over time was observed to be accelerated for boys with DCD compared to girls with DCD (30). Interestingly however, this study also found that physical activity did not mediate nor moderate the relationship between measures of body composition and DCD, even though overall, physical activity was negatively associated with body composition (30). However, this study is limited by a number of factors that warrant consideration in further work. Indeed, most studies that have examined the relationships among DCD, physical activity and body composition are limited in a number of important ways. These are described in detail in the sections that follow.

The first relates to the measure commonly used to classify children as overweight or obese. Body Mass Index (BMI) is one of the most common measures used to classify individuals as being overweight or obese. However, since BMI calculation is based only on weight and height measurements, its use as a measure of obesity is limited. BMI is a less sensitive measure of body fat compared to direct measures such as BOD POD and bioelectrical impedance (39, 46). BMI may not accurately reflect the changes in body fat and muscle mass that occur with age and maturity. Generally, an individual's percentage of body fat is known to increase with age while muscle mass is known to decrease with age (46). However, BMI calculated from an individual's body weight and height may not reflect these changes in body composition. For example, children who gain muscle mass without any increase in height will have a higher BMI score, therefore overestimating the percentage of body fat, while children who gain fat mass accompanied by an increase in height will have a lower BMI score, therefore underestimating the percentage of body fat. Some cross-sectional studies that have used other measures of adiposity such as waist circumference and percent body fat have reported that children with DCD have higher waist circumference and higher percent body fat than typically developing children (14, 17, 28, 49, 55). Previous longitudinal studies have also examined the association between DCD and waist circumference and found the difference in waist circumference between groups to increase over time (14, 30). Although percent body fat has been examined in cross-sectional studies, longitudinal studies are lacking that examine its trajectories over time.

Another limitation is that most previous studies examining the relationship between motor coordination and physical activity have used self-reported questionnaires to assess physical activity in children (11, 16, 37, 42, 43, 50). In comparison to objective measures of physical activity, self-reported measures often overestimate physical activity in children and adolescents (20, 57). This may be because self-reported measures of physical activity are susceptible to social desirability and recall bias. Since it is socially desirable to be physically active, children may report more time and effort spent in physical activity then is actually the case. Also, due to differences in children's cognitive development and their ability to accurately recall information, self-reported questionnaires are less accurate measures of physical activity (5, 41, 47). Accelerometers provide an objective measure of both organized and unorganized physical activity. In addition, accelerometers can be used to assess the frequency, intensity, duration, and energy expenditure of physical activity (57). A few previous studies have examined the relationship between DCD and physical activity assessed using accelerometer. A study by Williams and colleagues (58) found that children in the middle and lowest tertile for their motor skill performance spent less time in moderate-to-vigorous physical activity than children in the highest tertile. Similar results were also reported in another study that examined quartiles of motor proficiency and accelerometer-assessed physical activity (59). Green and colleagues (25) found that boys with DCD participated less in moderate-to-vigorous physical activity compared to boys without DCD; however, there was no difference in activity levels between girls with and without DCD. Batey and colleagues found that children with DCD reported lower perceived ability and confidence completing physical activities compared to typically developing children (6). Similar to the findings reported by Green and colleagues (25), Batey and colleagues also found that boys with DCD participated less in moderate-to-vigorous physical activity, but there was no difference in activity levels between girls with and without DCD.

Physical inactivity may not be the only factor influencing the relationship between DCD and body composition measures. Results from a meta-analysis of cohort and case-control studies suggest an increase in odds of DCD for children born preterm and/or low birth weight (22). Some studies have also found an increased risk of overweight and obesity in children born with high birth weight (60, 61). Since birth weight is associated with both DCD (22), and overweight and obesity (60, 61), it is important to adjust for birth weight when examining the relationship between DCD and body composition in order to minimize bias when estimating the effect of DCD on body composition. As well, lower household income is also known to be associated with increased odds of obesity (32, 35). Results obtained from previous studies examining the relationship between DCD and body composition have not been adjusted for birth weight and household income.

Finally, most studies examining the relation between motor coordination and body composition have not used repeated assessment of motor coordination over time. While longitudinal studies have consistently shown that children with DCD do not outgrow their motor coordination difficulties, some studies have shown motor coordination abilities to differ across ages. For instance, studies done by Hands (27) and Li and colleagues (33) found that motor coordination for a few typically developing children became progressively worse over time, while a study by Cantell and colleagues (16) found that children experiencing moderate levels of coordination difficulties showed some improvements in their motor coordination over time. It is possible that children in these studies were misclassified as typically developing or children with DCD owing to these changes in motor coordination. In order to minimize misclassification, ideally motor coordination should be reassessed over time.

The purpose of this study is to examine the relationship between DCD and measures of body composition (percent body fat and BMI) in children over time adjusted for age at baseline, sex, annual household income, and child's birth weight. Specifically, the following research questions will be examined: 1) Do differences in percent body fat and BMI between children with DCD and those without vary or remain constant over time as children get older? 2) Does the relationship between DCD and body composition measures over time differ by sex? 3) Does engagement in moderate-to-vigorous level physical activity have any effect on the relationship between DCD and body composition measures? As a secondary objective, including both BMI and percent body fat will allow us to assess the robustness of the former as a proxy measure for adiposity in this population.

## 3.2 Methodology

### *3.2.1 Participants*

The Physical Health Activity Study Team (PHAST) project is a longitudinal study designed to examine children's anthropometry, physical activity, and development over a 5-year period. Details of the study have been reported in several previous publications (12, 13, 15). The current study is a longitudinal investigation of a subset of children who participated in the larger PHAST study. In this ancillary study, 126 children aged 12-13 years were enrolled and followed up annually for two years. Details of this sub-study have also been previously reported (13). All children were recruited from public schools in the Niagara Region of Southern Ontario, Canada. The Brock University Research Ethics Board and the regional school board approved the protocol for this study. Written informed consent was obtained from a parent or guardian of each child before the child's participation in the study. The flow of participants in the PHAST II study is presented in Appendix I.

*3.2.2 Probable Developmental Coordination Disorder (pDCD)*

The second version of the Movement Assessment Battery for Children (MABC-2) (29) was used to assess fine and gross motor coordination in children. The MABC-2 is divided into three age bands and the third age band (age 11-16 years) was used in this study. This test has eight items grouped into three components: manual dexterity, aiming and catching, and balance. MABC-2 was administered for all three years and an average score was calculated to ensure that children truly experienced motor difficulties. Children scoring at or below the 15$^{th}$ percentile on the average MABC-2 score are considered to have significant motor coordination difficulties. The MABC-2 is known to have good reliability and validity, when used with children in this age range (8, 29). The parent or guardian of a child was asked to complete a medical questionnaire, which was used to ensure that motor coordination difficulties were not due to the presence of other medical conditions. Participants' intellectual ability was assessed using the second version of the Kaufman Brief Intelligence Test (KBIT-2) (31). The MABC-2 and KBIT-2 were administered by an occupational therapist. This study did not assess the effect of motor coordination difficulties on activities of daily living and academic achievement. Since we did not assess all criteria for identification of DCD, the term ‘probable DCD’ (pDCD) was used to refer to the group of children with DCD.

*3.2.3 Body Composition Measures*

Relative body fat was assessed using the BOD POD, which uses whole body air displacement plethysmography to estimate fat and fat free mass. The BOD POD measured the child’s body mass and volume of air that the child’s body displaced while sitting in a chamber. Each child’s overall body density (mass divided by volume) information was then used to calculate relative percentages of body fat and lean muscle mass. Volume measurements were obtained twice and the average value was used for these calculations. Volume measurements were obtained during relaxed tidal breathing where the child was asked to breathe normally. Children were asked to wear a tight-fitting swimsuit and to remove all accessories (e.g., jewelry and eyeglasses) since clothing and accessories can affect the accuracy of weight and volume measurements. Children were also asked to wear lycra cap in order to compress air pockets within the hair. Lohman’s equation for children was used to calculate body fat (36).

Height was measured using a stadiometer and recorded to the nearest 0.1 cm. Weight was measured using an electronic weight scale and recorded to the nearest 0.1 kg. Height and weight measurements were obtained without shoes, with children wearing light clothing. BMI was calculated by dividing weight in kilograms over height in meter squared. Including BMI in the analysis will allow us to compare the results obtained using percent body fat to BMI.

*3.2.4 Physical Activity*

Physical activity was assessed using the RT3 Triaxial Actical Accelerometer, which was attached to a waist belt and placed over the child's right hip. Children were instructed to wear the accelerometer for seven consecutive days starting the day after laboratory assessments were completed. Further details regarding the use of accelerometer for assessing physical activity can be found in Baerg et al. (3). Each child was given a log book to record the times when the accelerometer was worn in the morning and taken off during the day or at night over the duration of seven days. The data obtained from the accelerometer were compared to the log book containing the times recoded by the participants. This was done to ensure that only the times when the participant indicated they wore the accelerometer were used for the analysis. During data clean, any activity counts that did not reflect the activity of the child (e.g., parents or siblings walking with the accelerometer) were excluded. This procedure ensured that the data reflected an accurate record of activity counts of the participant. Each participant's minute-by-minute data were used to group their activity minutes into sedentary, light, and moderate-to-vigorous intensity level of physical activity. Puyau and colleagues determined these activity thresholds by having children aged 7-18 years perform several different activities such as ball games, aerobics, walking, running, and playing video and computer games, and capturing these activities using an Actical accelerometer (44). The area under the Receiver Operating Characteristic curve for the sedentary-light, light-moderate, and moderate-vigorous thresholds were 0.85, 0.93, and 0.95, respectively (44). Since the classification accuracy for the thresholds is good, and the study sample and the type of accelerometer used by the study done by Puyau and colleagues are comparable to our study, we decided to adopt the cut-off points proposed by Puyau and colleagues. Sedentary activity was defined as having an activity count of less than 100 counts per minute, light activity was defined as having an activity count between 100 and less than 1500 counts per minute, moderate activity was defined as having an activity count between 1500 and less than 6500 counts per minute, and vigorous activity was defined as having an activity count of 6500 or greater per minute (44). Each child had worn the accelerometer for at least 600 minutes per day and at least 3 days per week.

*3.2.5 Birth Weight and Annual Household Income*

Parent completed medical history and demographic questionnaire was used to obtain information on children's birth weight and total annual household income. Birth weight was reported in pounds and ounces and was converted to grams. Annual household income was grouped based on the low income cut-offs proposed by Statistics Canada (51). Low income cut-offs is an income cut-off point below which a family will likely spend a large portion of its income on necessities such as food, clothing, and shelter when compared to an average family (51). These calculations are based on after-tax income, the size of the community, and the size of the family. Based on the 2006 census data, the low income cut-off points in the Niagara Region for a one person, two persons, three persons, four persons, and five persons in the household were $14,859, $18,085, $22,519, $28,095, and $31,992, respectively (40). Based on this information, the decision was made to group annual household income into less than $30,000 and $30,000 and over.

*3.2.6 Statistical Analysis*

Mixed effects modeling was used to examine the effect of pDCD on percent body fat and BMI over time adjusted for age at baseline, sex, birth weight, and annual household income. Time (in months) was modeled as a linear variable to examine if the difference in body composition measures between groups (pDCD and typical development) remained constant or varied over time. A random intercept for participants and a random slope for time were included in the mixed effects models for percent body fat and BMI. A time by pDCD status interaction was tested to determine if change in body composition measures varied over time by groups. A three-way interaction between time, pDCD status, and sex was tested to see if changes in body composition measures among the groups varied over time for boys and girls. Next, physical activity variable was introduced into the model to examine its effect on the relationship between pDCD and body composition. Two-way interaction terms between time and physical activity, and pDCD status and physical activity were tested to examine if body composition measures varied over time by physical activity levels, and if body composition measures varied by physical activity levels for children with and without pDCD. Statistical significance was set at 0.05 and all analyses were performed using SAS version 9.4.

## 3.3 Results

Descriptive characteristics of the participants at each assessment are reported in Table 1. Mean age of children at baseline was 12.4 years. At baseline, children with pDCD have 31% higher percent body fat, 15% higher BMI scores, and on average, spent

21% less time in moderate-to-vigorous physical activity when compared to their typically developing peers.

Tables 2 and 3 show the results obtained from the mixed-effects models predicting percent body fat and BMI, respectively. After adjusting for age at baseline, time, sex, annual household income, and birth weight, on average, children with pDCD had 10.3% higher body fat and 4.3 kg/m$^2$ higher BMI than typically developing children. The time by DCD interaction was significant for BMI suggesting that children with pDCD have an increase in BMI over time. The time by DCD interaction was not significant for percent body fat suggesting that children with pDCD have a higher percent body fat than typically developing children and that this difference is maintained over time. The two-way interaction between time and sex was significant for percent body fat only, suggesting that the percentage of body fat in girls is increasing over time. The three-way interaction term between time, sex, and pDCD was not significant for both body composition measures suggesting that the relationship between DCD and body composition did not differ over time by sex. Therefore, models were reduced to a model containing the significant two-way interaction term for percent body fat and BMI.

Next, the effect of engaging in moderate-to-vigorous physical activity on the relationship between pDCD and measures of body composition was examined. Results from mixed-effects models predicting percent body fat and BMI are presented in Tables 4 and 5, respectively. The results suggest that physical activity does not mediate the association between pDCD and body composition measures because there is no attenuation of the effect of DCD in the presence of physical activity. Time by physical activity interaction was not significant for both the outcomes. pDCD by physical activity interaction showed a trend toward statistical significance for percent body fat (p-value = 0.0543) and BMI (p-value = 0.0580). Although not statistically significant, the pDCD by physical activity interaction was graphed for percent body fat and BMI in order to better understand these relationships. For typically developing children, greater participation in moderate-to-vigorous level physical activity is associated with lower percent body fat and BMI scores. For children with pDCD, greater participation in moderate-to-vigorous level physical activity is associated with higher percent body fat and BMI scores. However, the change in percent body fat and BMI over time is not pronounced (Figures 1 and 2). Finally, annual household income and birth weight were not found to be significantly associated with any body composition measures.

### 3.4 Discussion

This study examined the relationship among pDCD, percent body fat, and physical activity over a period of two years. The results showed that children with pDCD have a higher body fat and BMI than typically developing children and that the difference between groups remains constant over the study period for body fat, while differences in BMI increase over time. Physical activity had, at best, marginal effects on the relationship between pDCD and percent body fat, and between pDCD and BMI.

The findings of this study are in agreement with previous longitudinal studies that have shown that children with pDCD have consistently higher BMI than typically developing children over time (14, 30). This, however, is the first longitudinal study to have shown that children with pDCD consistently have higher percent body fat than typically developing children over time, placing them at a higher risk of obesity-related comorbidities.

In this study, we also examined the effect of performing moderate-to-vigorous physical activity on the relationship between pDCD and body composition measures to directly test the activity-deficit hypothesis. The results showed that physical activity assessed using accelerometry had a minimal effect on this relationship. Differences in physical activity between groups do not explain why children with pDCD have higher body fat and BMI. This finding is consistent with a previous study, which found self-reported physical activity to be independently associated with BMI and waist circumference (30). Our results did show the possibility that the effect of physical activity on body composition may not be the same for children with and without pDCD. Indeed, Figures 1 and 2 show that increases in the amount of time spent in moderate-to-vigorous physical activity are associated with increases in percent body fat and BMI for children with pDCD. This counter-intuitive finding may be explained by the presence of small sample sizes in the group that achieved at least 70 minutes of moderate-to-vigorous physical activity. Only five children (pDCD: n=1; Typical Development: n=4) participated in 70-90 minutes of moderate-to-vigorous physical activity, and only 2 children participated (pDCD: n=1; Typical Development: n=1) in greater than 90 minutes of moderate-to-vigorous physical activity. Mean percent body fat and BMI for children with and without pDCD across physical activity levels are reported in Table 6.

The fact that increased moderate-to-vigorous physical activity in children with DCD is not associated with decreases in percent body fat remains a curious finding. One explanation for this relates to a possible imbalance in the energy consumption (caloric intake) and energy output in children with pDCD. For example, children with pDCD may experience difficulties preparing healthy meals, especially if preparing such meals requires the use of fine motor skills. Instead, they may be more likely to consume packaged and frozen foods that may have a high fat and sugar content. Therefore, energy consumption in children with pDCD may be even greater than typically developing children explaining why these children have increased percent body fat and BMI compared to typically developing children. Even at higher levels of activity, energy consumption may be exceeding energy expenditure. There are no existing studies that consider dietary intake to physical activity in children with DCD. Future work should examine if imbalances in energy consumption and expenditure contributes to unhealthy weight gain in children with DCD.

Another explanation for why differences in physical activity do not explain differences in body composition measures may be that the majority of Canadian children are physically inactive and do not accumulate the recommended 60 minutes of moderate-to-vigorous physical activity daily (19, 52). Results from the Canadian Health Measures Survey suggests that only 9% of boys and 4% of girls accumulate 60 minutes of moderate-to-vigorous physical activity on at least 6 days a week (19). Similarly, in this study only 5.6% of children accumulated at least 60 minutes of moderate-to-vigorous physical activity. Since the majority of children in the population do not meet the recommended level of physical activity, any mediating effects of physical activity were unlikely to be found. If all children are relatively inactive, then the overall variability in physical activity in the population is reduced, and therefore there is reduced power to detect significant differences between groups.

Most previous studies examining the association between pDCD and body composition have used an indirect measure of body fat (BMI) and self-reported measure of physical activity. This study addressed these limitations by using a direct measure of body fat (BOD POD) and an objective measure of physical activity (accelerometer). The results obtained in this study are comparable to those obtained when using BMI and self-reported measure of physical activity. Research has shown both methods of assessing physical activity to have moderate-to-high correlations with each other. A systematic review comparing indirect and direct measures of physical activity in the pediatric population found correlations between -0.56 and 0.89 (1). Likewise, high correlations were also found between percent body fat and BMI (34, 38). The current study found correlations between percent body fat and BMI to be 0.81 (year one), 0.79 (year two), and 0.75 (year three). Similar correlation coefficients were also reported by other studies. A study done in adolescents aged 11-17 years reported correlation between BMI and percent body fat to be 0.71 among boys and 0.72 among girls (38). Another study conducted in 10-19 year old adolescents found the correlation to vary from 0.84-0.89 in boys and 0.83-9.86 in girls (34). Since there is no single ‘gold standard’ for assessing physical activity, and given the relatively high correlations among these measures, the appropriate method for assessing body composition and physical activity depends on several factors such as the number of participants and budget constraints. The results of this study indicate that although percent body fat and objective assessment of physical activity are superior measures, BMI and self-reported measure of physical activity are still useful measures for assessing body composition and physical activity in a field-based assessment, especially in a large population sample or when resources are limited.

Finally, this study did not find an association between body composition measures and birth weight. Factors such as gestation over-nutrition, gestational diabetes mellitus, maternal excess weight gain and obesity status, prolonged gestation, genetic predisposition, parental body size, and gestational age are known to have an effect on birth weight and risk of later obesity (61, 21, 45, 53). However, these factors were not taken into consideration in this study. Examining these factors may provide further understanding of the association among birth weight, pDCD, and body composition. Further, no association was found between annual household income and body composition. This may be because on average, BMI (23.5 vs. 22.2 kg/m$^2$) and percent body fat (23.0 vs. 23.7) scores were similar in both income groups (less than $30,000 and $30,000 and over).

As discussed above, accelerometers can be used to objectively assess both organized and unorganized physical activity in children as well as capture the frequency, intensity, and duration of the activity which most self-report questionnaires are unable to capture. However, even this technology is not without limitations. For example, water-based activities such as swimming are not captured using accelerometers. In future, it would be beneficial to use both an objective measure of physical activity as well as self-report questionnaire and diaries to accurately assess physical activity in children.

Strengths of this study include the longitudinal study design to examine changes in body composition measures over time, and use of a more sensitive and direct measure for body fat (BOD POD) and energy expenditure (accelerometer). This study also used repeated measures of MABC-2 to assess motor coordination, which helped minimize misclassification of children into pDCD and typically developing groups. A limitation of this study is that the effect of motor coordination on academic achievement and everyday functioning was not assessed in this study.

In conclusion, children with pDCD have higher body fat and BMI than typically developing children and this difference does not diminish over the study period. Physical activity was found to have a minimal effect on the relationship between pDCD and body composition. Therefore, future studies should examine the role of other factors such as diet in explaining the difference in body composition in children with and without DCD. Exploring other factors such as diet is also necessary so that intervention programs can be designed to address the problem of unhealthy weight gain in children with DCD. DCD and overweight/obesity are both associated with negative health outcomes including poor cardiovascular and psychological outcomes. Therefore, children with DCD who are also overweight or obese may have an increased risk of developing chronic diseases such as coronary artery disease, hypertension, type 2 diabetes, and poor psychological outcomes such as global self-worth due to the presence of both conditions concomitantly. Future studies should also examine secondary consequences in children with DCD who are overweight or obese.

**Table 1: Descriptive characteristics of the participants at each wave**

| | Time 1 | Time 2 | Time 3 |
|---|---|---|---|
| **N** | 126 | 105 | 86 |
| **Age (yrs), mean (SD)** | 12.4 (0.5) | 13.2 (0.5) | 14.7 (0.4) |
| **Sex, n (%)** | | | |
| **Male** | 74 (58.7) | 62 (59.1) | 52 (60.5) |
| **Female** | 52 (41.3) | 43 (41.0) | 34 (39.5) |
| **pDCD[1], n (%)** | 60 (47.6) | 44 (41.9) | 33 (38.4) |
| **Body Fat (%), mean (SD)** | | | |
| **pDCD** | 28.8 (11.1) | 29.8 (10.3) | 29.2 (11.0) |
| **Typically developing** | 20.0 (9.7) | 20.1 (10.1) | 18.0 (9.4) |
| **All** | 24.2 (11.3) | 24.2 (11.2) | 22.3 (11.4) |
| **BMI (kg/m$^2$), mean (SD)** | | | |
| **pDCD** | 23.6 (6.0) | 24.6 (6.3) | 25.6 (6.4) |
| **Typically developing** | 20.1 (3.9) | 20.7 (3.8) | 21.3 (3.6) |
| **All** | 21.8 (5.3) | 22.4 (5.3) | 22.9 (5.3) |
| **Moderate-to-Vigorous Physical Activity (minutes/week), mean (SD)** | | | |
| **pDCD** | 24.5 (15.9) | 22.7 (16.8) | 24.4 (17.3) |
| **Typically developing** | 31.0 (20.4) | 30.3 (20.2) | 26.9 (16.5) |
| **All** | 28.0 (18.7) | 27.5 (19.3) | 25.9 (16.7) |

**[1]pDCD = Probable Developmental Coordination Disorder**

**Table 2: Mixed-effects models predicting percent body fat from age at baseline, time, sex, pDCD, annual household income, and child's birth weight**

| | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
|---|---|---|---|---|---|---|---|---|
| | **Estimate** | **p-value** | **Estimate** | **p-value** | **Estimate** | **p-value** | **Estimate** | **p-value** |
| **Intercept** | 23.38 | <.0001 | 22.12 | <.0001 | 18.97 | <.0001 | 17.50 | <.0001 |
| **Age at baseline (yrs)** | 2.43 | 0.2095 | 3.03 | 0.1282 | 2.67 | 0.1313 | 3.35 | 0.0652 |
| **Time (months)** | -0.03 | 0.2990 | -0.03 | 0.2975 | -0.03 | 0.3147 | -0.03 | 0.3133 |
| **Sex (Female)** | | | 2.52 | 0.2233 | | | 2.86 | 0.1304 |
| **pDCD**[1] | | | | | 9.09 | <.0001 | 9.18 | <.0001 |

| | Model 5 | | Model 6 | | Model 7 | | Model 8 | |
|---|---|---|---|---|---|---|---|---|
| | **Estimate** | **p-value** | **Estimate** | **p-value** | **Estimate** | **p-value** | **Estimate** | **p-value** |
| **Intercept** | 21.41 | 0.0007 | 21.54 | 0.0006 | 21.64 | 0.0005 | 13.31 | 0.0782 |
| **Age at baseline (yrs)** | 3.39 | 0.0831 | 3.39 | 0.0835 | 3.34 | 0.0859 | 2.97 | 0.1268 |
| **Time (months)** | -0.02 | 0.5244 | -0.05 | 0.1608 | -0.12 | 0.0006 | -0.18 | <.0001 |
| **Sex (Female)** | 2.94 | 0.1289 | 2.94 | 0.1286 | 2.31 | 0.2301 | 4.32 | 0.0899 |
| **pDCD** | 10.33 | <.0001 | 10.12 | <.0001 | 10.33 | <.0001 | 11.98 | <.0001 |
| **Income (< $30,000)** | -4.03 | 0.0896 | -4.04 | 0.0894 | -3.93 | 0.0957 | 3.84 | 0.1006 |
| **Birth weight** | -0.00099 | 0.5564 | -0.001 | 0.5517 | -0.00098 | 0.5590 | -0.00097 | 0.5595 |
| **Time*pDCD** | | | 0.08 | 0.1540 | | | 0.13 | 0.0561 |
| **Time*Sex** | | | | | 0.24 | <.0001 | 0.28 | <.0001 |
| **Sex*pDCD** | | | | | | | -4.56 | 0.2253 |
| **Time*Sex*pDCD** | | | | | | | -0.11 | 0.2861 |

[1]**pDCD = Probable Developmental Coordination Disorder**

**Table 3: Mixed-effects models predicting BMI from age at baseline, time, sex, pDCD, annual household income, and child's birth weight**

| | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | p-value | Estimate | p-value | Estimate | p-value | Estimate | p-value |
| **Intercept** | 20.90 | <.0001 | 20.47 | <.0001 | 19.13 | <.0001 | 18.63 | <.0001 |
| **Age at baseline (yrs)** | 2.38 | 0.0083 | 2.59 | 0.0054 | 2.48 | 0.0034 | 2.72 | 0.0019 |
| **Time (months)** | 0.07 | <.0001 | 0.07 | <.0001 | 0.07 | <.0001 | 0.07 | <.0001 |
| **Sex (Female)** | | | 0.86 | 0.3642 | | | 0.99 | 0.2661 |
| **pDCD[1]** | | | | | 3.63 | <.0001 | 3.66 | <.0001 |

| | Model 5 | | Model 6 | | Model 7 | | Model 8 | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | p-value | Estimate | p-value | Estimate | p-value | Estimate | p-value |
| **Intercept** | 22.42 | <.0001 | 22.48 | <.0001 | 22.42 | <.0001 | 19.12 | <.0001 |
| **Age at baseline (yrs)** | 2.94 | 0.0016 | 2.95 | 0.0016 | 2.94 | 0.0016 | 2.80 | 0.0027 |
| **Time (months)** | 0.07 | <.0001 | 0.06 | <.0001 | 0.07 | <.0001 | 0.05 | 0.0004 |
| **Sex (Female)** | 0.87 | 0.3333 | 0.87 | 0.3364 | 0.86 | 0.3391 | 1.68 | 0.1606 |
| **pDCD** | 4.33 | <.0001 | 4.22 | <.0001 | 4.33 | <.0001 | 5.00 | <.0001 |
| **Income (< $30,000)** | -1.54 | 0.1631 | -1.55 | 0.1620 | -1.54 | 0.1633 | 1.52 | 0.1679 |
| **Birth weight** | -0.001 | 0.1715 | -0.001 | 0.1699 | -0.001 | 0.1716 | -0.001 | 0.1719 |
| **Time*pDCD** | | | 0.04 | 0.0136 | | | 0.06 | 0.0055 |
| **Time*Sex** | | | | | 0.0034 | 0.8298 | 0.02 | 0.2896 |
| **Sex*pDCD** | | | | | | | -1.85 | 0.2957 |
| **Time*Sex*pDCD** | | | | | | | -0.04 | 0.1600 |

**[1]pDCD = Probable Developmental Coordination Disorder**

**Table 4: Mixed-effects models predicting percent body fat from age at baseline, time, sex, pDCD, annual household income, child's birth weight, and physical activity**

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | Estimate | p-value | Estimate | p-value | Estimate | p-value |
| **Intercept** | 22.88 | 0.0004 | 22.10 | 0.0006 | 23.57 | 0.0003 |
| **Age at baseline (yrs)** | 3.822 | 0.0584 | 3.83 | 0.0589 | 3.86 | 0.0578 |
| **Time (months)** | -0.14 | 0.0004 | -0.06 | 0.2984 | -0.15 | 0.0004 |
| **Sex (Female)** | 2.13 | 0.2888 | 2.34 | 0.2470 | 1.88 | 0.3511 |
| **pDCD[1]** | 10.42 | <.0001 | 10.50 | <.0001 | 8.43 | 0.0004 |
| **Income (< $30,000)** | -3.39 | 0.1662 | -3.29 | 0.1812 | -3.46 | 0.1603 |
| **Birth weight** | -0.001 | 0.4524 | -0.001 | 0.4515 | -0.001 | 0.4780 |
| **Time*Sex** | -0.21 | 0.0012 | 0.20 | 0.0016 | 0.21 | 0.0014 |
| **MVPA[2]** | -0.0095 | 0.6282 | 0.01 | 0.5464 | -0.04 | 0.1454 |
| **MVPA*Time** | | | -0.003 | 0.0824 | | |
| **MVPA*pDCD** | | | | | 0.08 | 0.0544 |

**[1]pDCD = Probable Developmental Coordination Disorder**
**[2]MVPA = Moderate-to-vigorous Physical Activity**

**Table 5: Mixed-effects models predicting BMI from age at baseline, time, sex, pDCD, annual household income, child's birth weight, and physical activity**

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | Estimate | p-value | Estimate | p-value | Estimate | p-value |
| **Intercept** | 23.14 | <.0001 | 23.03 | <.0001 | 23.37 | <.0001 |
| **Age at baseline (yrs)** | 3.10 | 0.0014 | 3.10 | 0.0014 | 3.10 | 0.0014 |
| **Time (months)** | 0.05 | <.0001 | 0.06 | 0.0004 | 0.05 | <.0001 |
| **Sex (Female)** | 0.82 | 0.3718 | 0.85 | 0.3579 | 0.75 | 0.4192 |
| **pDCD**[1] | 4.24 | <.0001 | 4.25 | <.0001 | 3.68 | 0.0003 |
| **Income (< $30,000)** | -1.24 | 0.2745 | -1.23 | 0.2803 | -1.25 | 0.2699 |
| **Birth weight** | -0.001 | 0.1228 | -0.001 | 0.1228 | -0.001 | 0.1283 |
| **Time*pDCD** | 0.04 | 0.0065 | 0.04 | 0.0103 | 0.05 | 0.0057 |
| **MVPA**[2] | -0.006 | 0.2612 | -0.003 | 0.6922 | -0.01 | 0.0408 |
| **MVPA*Time** | | | -0.0004 | 0.3718 | | |
| **MVPA*pDCD** | | | | | 0.02 | 0.0580 |

**[1]pDCD = Probable Developmental Coordination Disorder**
**[2]MVPA = Moderate-to-vigorous Physical Activity**

**Table 6: Means and standard deviations for percent body fat and BMI by minutes spent in moderate-to-vigorous physical activity in children with and without pDCD**

| | pDCD[1] | | | | Typically development | | | |
|---|---|---|---|---|---|---|---|---|
| | Percent Body Fat | | BMI | | Percent Body Fat | | BMI | |
| **Time spent in moderate-to-vigorous physical activity (min)** | **n** | **Mean (SD)** | **n** | **Mean (SD)** | **n** | **Mean (SD)** | **n** | **Mean (SD)** |
| **<20** | 54 | 30.0 (11.8) | 55 | 25.0 (6.0) | 64 | 22.1 (10.2) | 63 | 21.5 (4.2) |
| **20 to <50** | 52 | 29.3 (8.9) | 52 | 23.8 (6.3) | 70 | 18.5 (9.4) | 71 | 20.3 (3.3) |
| **50 to <70** | 4 | 24.7 (15.7) | 4 | 21.5 (4.9) | 21 | 15.8 (10.0) | 21 | 20.0 (3.5) |
| **70 to <90** | 1 | 16.9 | 1 | 20.0 | 4 | 19.5 (8.2) | 4 | 19.0 (1.4) |
| **≥90** | 1 | 30.4 | 1 | 27.9 | 1 | 11.3 | 1 | 21.6 |

**[1]pDCD = Probable Developmental Coordination Disorder**

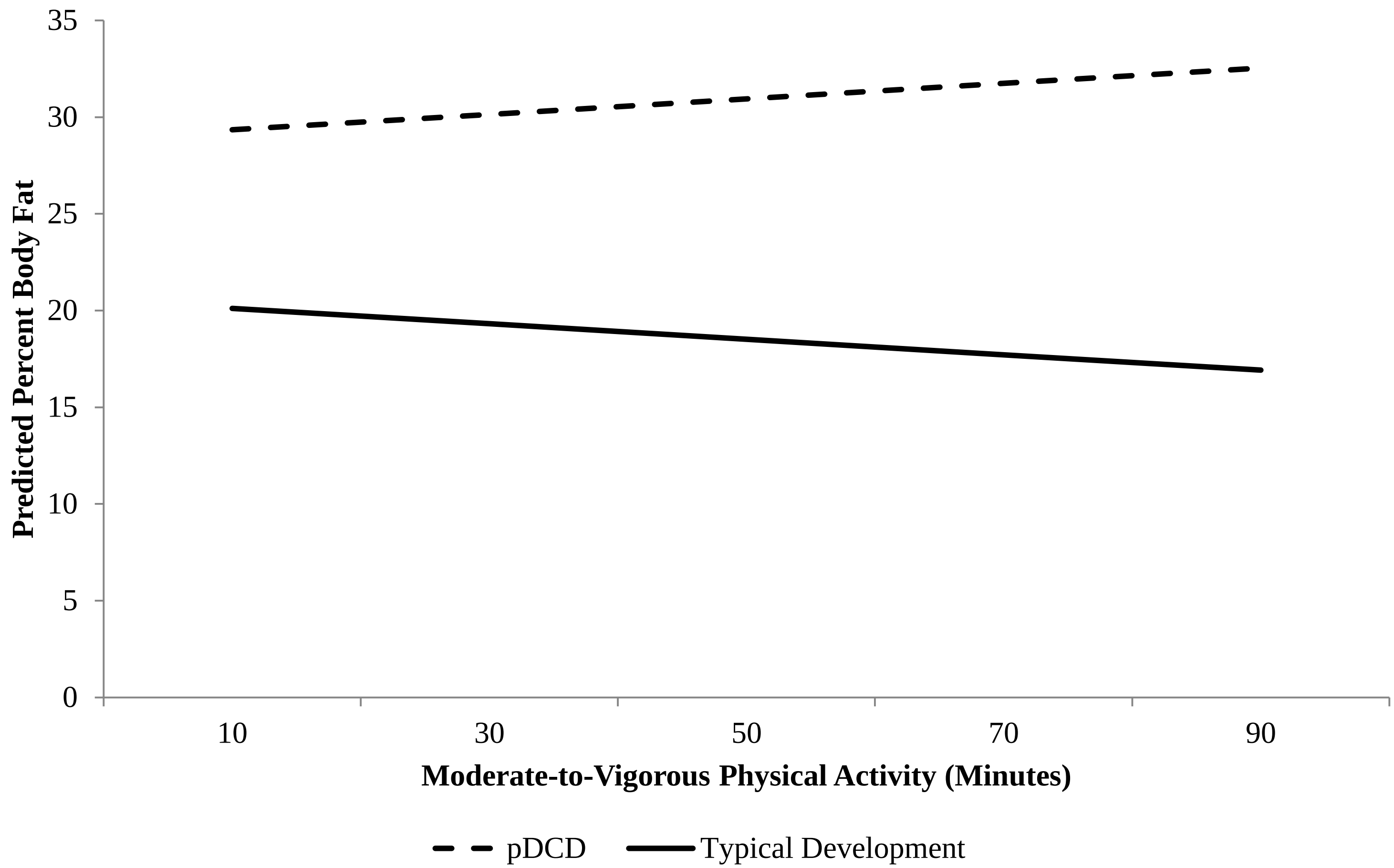


**Figure 1: Predicted percent body fat by moderate-to-vigorous physical activity for children with and without pDCD**

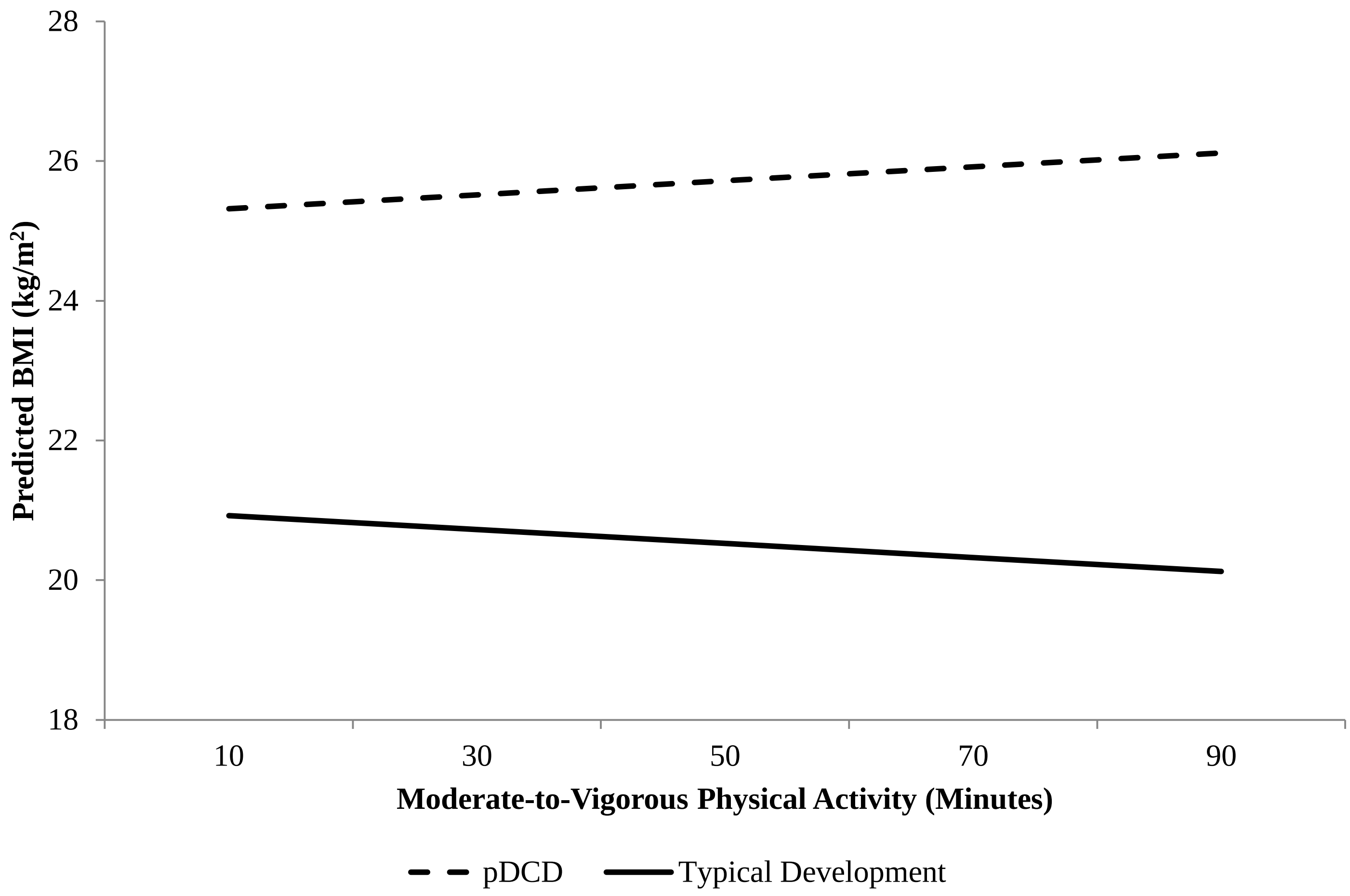


**Figure 2: Predicted BMI by moderate-to-vigorous physical activity for children with and without pDCD**

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# CHAPTER 4

Divya Joshi, Cheryl Missiuna, Steven Hanna, John Hay, Brent E. Faught, John Cairney. Relationship among developmental coordination disorder, obesity, and global self-worth in children over time (Submitted to *Child Development*, May 24, 2015).

**Relationship among developmental coordination disorder, obesity, and global self-worth in children over time**

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**Abstract**

**Background:** Previous studies have independently examined the association between self-worth and overweight/obesity, and between self-worth and motor coordination problems. However, the combined effect of both developmental coordination disorder (DCD) and overweight/obesity on global self-worth is not known. Therefore, the purpose of this study is to examine the relationship among global self-worth, probable DCD (pDCD), and overweight/obesity at baseline and over time.

**Methods:** Data from the Physical Health Activity Study Team (PHAST) project were used for this study. A total of 2,278 (pDCD=103) children aged 8-10 years were included in this longitudinal study at baseline. Multiple linear regression was used to examine the association among self-worth, pDCD, and overweight/obesity at baseline. Mixed-effects modelling was used to estimate change in self-worth in children over time.

**Results:** Children with both pDCD and overweight/obesity and children with either of these conditions alone report a lower self-worth than the control group. The difference in self-worth between groups remains mainly constant over time.

**Conclusions:** Lower self-worth is associated with many negative health and social outcomes. Future studies should identify mechanisms explaining why children with both conditions report lower self-worth

**Keywords:** Developmental Coordination Disorder, Global self-worth, Obesity, Children

### 4.1 Introduction

Self-worth is an important component of overall psychological well-being. Global self-worth refers to a child's perceptions of self-competence, satisfaction and overall positive feelings of self [1]. Low self-worth in children is of concern because it is known to be associated with several other health and psychosocial related outcomes. For example, having a positive sense of self is associated with success in important social domains such as school performance and forming friendships [2]. Studies have found an association between low global self-worth and higher levels of body image concerns such as body dissatisfaction, eating disorders, dieting, and drive for thinness [3-4]. Boys and girls with lower self-worth also reported higher rates of peer victimization and anxiety symptoms than their peers with higher self-worth, who appear to be more resilient to stress and fear [5-6]. There is also a strong association between low self-worth and depressive symptoms [7-8], and depression in turn is associated with other negative outcomes such as suicide [9-10].

The presence of chronic disease and disability can negatively influence a child's perception of their own self-worth. Developmental coordination disorder (DCD) is one such condition worthy of further consideration. A neurodevelopmental condition resulting in movement impairment that is not related with any identifiable physical or intellectual disorders, DCD has a negative impact on children's academic achievements and ability to perform daily activities [11]. About 1.8% to 6% of children are estimated to have this disorder [12-14]. Importantly, because DCD can have a significant impact on a child's ability to play with other children, and to participate more broadly in school, recreational and home activities, this condition not only affects motor behaviour, but also psychological well-being including self-perceptions of competence and worth [15]. Yet, while previous studies have examined the association between DCD and global self-worth, the results are conflicting: some studies have shown that children with DCD report lower levels of global self-worth than children without DCD [16-18], while other have failed to find an association [19-23]. There are several possible explanations for these discrepant findings.

First, the relationship between DCD and global self-worth may differ by gender. Research suggests that boys and girls have similar levels of self-esteem in childhood, but gender differences in self-esteem start to develop during adolescence with girls reporting lower levels of self-esteem than boys [24]. Explanations for this include both biological and psychosocial mechanisms. For example, some evidence suggests that lower global self-worth in adolescent boys and girls may be associated with maturational changes during puberty, especially changes related to development of breasts and onset of menarche in girls [24]. There is also an increased expectation on girls to follow socially constructed ideas of beauty [25]. Therefore, physical changes in body shape during puberty may have a stronger effect on girls' self-worth compared to boys [24]. While these experiences are not specific to children with DCD, motor coordination problems may have a negative impact on children's self-worth [16-18]. Children with DCD experience difficulty in performing activities of daily living such as dressing and self-care tasks. For example, girls with DCD may require greater effort in dressing, using a hair dryer, or putting on makeup. Difficulty in performing such daily activities places these children at an increased risk for lower perceived self-worth. The study by Skinner and Piek had twice as many girls than boys in their sample, which may explain their significant findings [18]. This is also supported by Rose and colleagues who found that children with poor motor coordination had lower self-worth score compared to their well-coordinated peers, and this relationship differed by gender with girls with coordination difficulties reporting the lowest perceived self-worth score (gender by coordination interaction) [16].

In addition to gender, age or developmental stage is also related to changing perceptions of self-worth. Skinner and Piek found that adolescents aged 12 to 14 years perceived themselves to be less competent and reported lower self-worth score compared to younger children aged 8 to 10 years [18]. Perhaps, the difference in self-worth between the two age groups may be due to their cognitive development. As children get older and develop cognitively, they may evaluate their self-worth based on the feedback obtained from family members, teachers, and classmates or based on comparisons of self and peers [24]. Lower self-worth in adolescents may also be associated with changes in their body shape, size, and weight over time [24]. While older children generally report lower self-worth, those with DCD may be at a further disadvantage. Children with DCD report lower perceptions of social support, have fewer friends, feel more socially isolated, and are more likely to be overweight/obese which may contribute to their lower perceived self-worth [12, 26-27]. However, since previous studies have been cross-sectional, they have been unable to test whether aging influences the association between DCD and self-perceptions of worth.

Finally, discrepancies in results may also be due to the differences in sample size between the studies. For instance, studies done by Piek and colleagues had a relatively small sample size of 72 and 86 participants, respectively [21-22]. Low statistical power associated with a small sample size may have lowered their chance of finding a true effect.

While DCD may impact perceptions of self-worth in children, other health-related issues can also negatively impact self-perceptions. Overweight/obesity is a significant public health concern affecting 26% of children in Canada [28]. Like DCD, there is reason to suspect that overweight/obesity will have a direct and negative effect on self-perceptions of worth in children adolescents. Indeed, previous studies have shown that overweight and obese children feel physically unattractive and experience social rejection, discrimination, ridicule, and are blamed for their condition [29]. Consequently, obesity can have a significant negative impact on psychological well-being. Studies have shown reductions in athletic competence, perception of physical appearance, social functioning, and quality of life in obese children compared to healthy weight children [30-34]. Overweight and obese children also demonstrated higher body dissatisfaction than healthy weight children [32]. Moreover, overweight and obese children have been shown to report lower self-worth than their peers with healthy body weight [30, 35]. Lower self-worth in overweight and obese children is of concern because it is known to be associated with higher rates of eating disorders, depression symptoms, and risky health behaviours such as smoking and alcohol consumption [35].

Unfortunately, DCD and overweight/obesity are not isolated conditions. Children with DCD have been shown to be at higher risk of being overweight or obese relative to typically developing children [12, 26, 36-37]. It is estimated that by ages 8 or 9, more than half of all children with DCD are overweight or obese [26]. Given that overweight/obesity is associated with lower self-worth in typically developing children, it is interesting to examine whether lower self-worth in children with DCD is related to their relative body weight. To our knowledge no study has examined global self-worth in children with both DCD and who are overweight/obese. We hypothesize that overweight/obese children with DCD experience a kind of double jeopardy related both to relative weight status and poor motor ability. In other words, there may be a compounded effect of both excess body weight and motor coordination on perceptions of self-worth. To date, this hypothesis has not been tested in the literature.

As noted previously, perceptions of global self-worth in children have been shown to differ by age [18], and the association between motor coordination problems and self-worth may be stronger in older children [18]. However, this work is limited due to its reliance on cross-sectional data. As a result, studies have been unable to examine change in self-worth score as children age. Longitudinal studies examining the changes in global self-worth score over time are required to understand the impact of aging on the association between DCD and self-worth. It is also not yet known if age influences the cumulative impact of both DCD and overweight/obesity on self-worth. Therefore, in this study, we will examine the relationship among DCD, overweight/obesity and self-worth over time, to examine the effect of aging on these associations. The following research questions will be examined: Is there a relationship among global self-worth, DCD, and overweight/obese statuses at baseline after adjusting for age, gender, and overweight/obesity status at later time points? What influence does aging (time) have on the association among DCD, relative body weight and self-worth? Does gender influence the association among DCD, relative body weight and self-worth?

## 4.2 Methodology

### *4.2.1 Study Participants*

Physical Health Activity Study Team (PHAST) project is a longitudinal cohort study that began during the 2004-2005 school year. This study included all children in grade four enrolled in the public school system in the southern region of Ontario, Canada. Permission to recruit participants was obtained from 75 of 92 (83%) schools and parental consent was obtained for 2278 of 2378 (95.8%) children. The flow of participants in the PHAST I study is presented in Appendix I and retention of participants over multiple waves is presented in Appendix II. Data collection began in the spring of 2005 with reassessments done in fall of 2005, spring and fall of 2006, spring and fall of 2007, fall of 2008, and fall of 2009. Therefore, data was collected at eight different time points over a period of five years. Trained research assistants using testing protocols established at baseline completed all data collection. Ethics approval was obtained from the region's district school board and from the research ethics board at Brock University.

### *4.2.2 Measurement of Study Variables*

#### *4.2.2.1 Global self-worth*

The subscale from the Harter's Self-perception Profile for Children was used to assess global self-worth in children [38]. This is a self-report questionnaire, which assesses self-perception in six areas: physical appearance, athletic competence, scholastic competence, social acceptance, behavioural conduct, and global self-worth (Appendix IV). The full instrument consisted of a total of 36 items (six items for each subscale) and each item was divided into two tasks. The first task required a participant to decide which child in the statement was most like him or her. After making this decision, the participant was asked to decide if the child in the statement was "sort of true for me" or "really true for me". Each item was scored from 1 to 4 and the total scores for the global self-worth subscale can range from 6 to 24 with lower scores indicating low perceived competence. Construct validation studies have shown the global self-worth subscale to have significant, negative correlations with self-reported depression (r= -0.67) and the Trait Anxiety Scale (r= -0.56), in children ages 8 to 12 years of age [39]. The internal consistency is estimated at 0.80 and the four-week test-retest reliability is estimated at 0.86 [39].

*4.2.2.2 Assessment of Motor Coordination*

The short form of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP-SF) was used to evaluate motor coordination. The BOTMP-SF uses selected items from the full instrument to evaluate all components of motor coordination. The short form has been validated against the full instrument in children aged 8 to 14 years and correlations between 0.90 and 0.91 were reported [40]. Motor coordination was evaluated once over the study period by a trained research assistant who administered the test individually to each child in the school's gymnasium during regular school hours. Appropriate measures were taken to minimize distractions and ensure privacy. Children scoring lower than the 6$^{th}$ percentile on the BOTMP-SF were identified as "probable" cases of DCD (pDCD). The term "probable" was used because cases were identified by research assistants and no formal diagnosis was made by a physician. Also, this study did not assess criterion B of the Diagnostic and Statistical Manual of Mental Disorders, version IV (DSM IV). However, all children with known learning or physical disabilities were excluded from the study (criteria C and D). This field-based assessment has been validated and the procedure has been published previously [41]. The results showed that 88% of children who scored below the 6$^{th}$ percentile on the BOTMP-SF met the criteria for case identification of DCD based on the 15$^{th}$ percentile on the Movement Assessment Battery for Children [41].

*4.2.2.3 BMI*

The child's height was measured using a stadiometer and recorded to the nearest 0.2 cm. While obtaining height measurements, the child was instructed to stand erect with heels together. Body weight was measured using a medical weight scale and recorded to the nearest 0.1 kg. Height and weight measurements were obtained without footwear and in clothing required for physical education class. Weight in kilograms divided by height in meter squared was used to calculate BMI for each child. Overweight/obesity was defined as having a BMI score greater than or equal to 85$^{th}$ percentile value specified in the CDC growth charts. BMI cut-points specified in the CDC growth charts were age and gender specific.

*4.2.3 Statistical Analysis*

Children were grouped into four groups based on baseline assessment of motor coordination and anthropometry: pDCD and overweight/obese, only pDCD, only overweight/obese, and typically developing children and who are not overweight/obese. In this study, we are using baseline data to create clinically meaningful groups in order to examine the effects of co-morbid conditions (DCD and overweight/obesity) on self-worth scores in children aged 8-9 years. Classification of children into these groups uses an approach that is consistent with estimating the effect of co-morbid disease conditions in children: for example, studies examining co-morbid conditions of DCD and learning disorder, and DCD and attention deficit hyperactivity disorder have grouped children based on the presence of one or more disorders [42-43]. Using clinical criteria, children are grouped as having both conditions, any one condition, or neither of the two conditions. Similarly, in this study, children are grouped based on the DCD case identification criteria and overweight/obesity criteria discussed above. We do this at baseline because at ages 8-9 children undergo significant cognitive and emotional development, and have the capacity to organize thoughts and form opinions. Assessment at this developmental stage is also important because it allows us examine children's perception of self-worth during childhood and before puberty-related changes begin to take place.

Multiple linear regression was used to predict global self-worth score across the groups at baseline, controlling for the age and gender. Mixed effects modeling was used to examine the change in global self-worth score across the groups over time, adjusted for their overweight/obesity status at later time points. Time was modelled as number of months since baseline. Random intercept for participants and random slope for time were included in the analysis. A group by gender interaction term was tested to determine if the difference in self-worth score differed by gender. A time by group interaction was tested to determine if the difference in global self-worth score increased, decreased, or remained constant over time. To examine if this relationship is influenced by overweight/obesity status at later time points, a three-way interaction term between time, group, and overweight/obesity status at later time point was tested. This is important because while DCD is a chronic condition that persists overtime [44-45], relative weight status can change.

## 4.3 Results

In this sample, 103 children (4.5%) were identified as having probable DCD (pDCD). Table 1 shows the descriptive characteristics of the participants at eight time points. At baseline, children were grouped into those identified as having pDCD, being overweight/obese, having both these conditions, and having neither of these conditions (reference group). There was a significant difference in mean global self-worth score among the four groups at baseline ($F = 7.98$, $p = <.0001$). A post-hoc Tukey's test showed that children having only pDCD and children having only overweight/obesity had significantly lower mean global self-worth score than children with typical development and healthy body weight, and with children with both conditions. Proportions of children in each group that are overweight/obese at later time points are provided in Table 2.

Multiple linear regression model predicting children's self-worth score by overweight/obesity and pDCD groups at baseline is presented in Table 3. The results suggest that children with both pDCD and overweight/obesity, only pDCD, and only overweight/obesity had lower average self-worth score (1.20, 1.55, and 0.78 points, respectively) at baseline, when compared to typically developing, healthy weight children. Children with only pDCD reported the lowest global self-worth score at baseline. Children with both conditions reported a lower self-worth score than children with only overweight/obesity.

Results from mixed-effects models predicting global self-worth score by groups (defined at baseline), time, age, and gender are presented in Table 4. While children in all three groups had lower self-worth score than the reference group, children with both conditions reported having the lowest global self-worth score over time indicating a combined effect of both motor coordination and relative weight status on self-worth. A two-way interaction term between time and groups was tested to examine whether being overweight/obese and having pDCD at baseline is associated with long-term changes in perceived self-worth (Model 1, Table 4). The interaction term was not significant suggesting that although there were differences in self-worth scores between groups, the differences remained constant over time.

Next, a three-way interaction term between time, group, and overweight/obesity status at later time points was tested to see whether being overweight/obese and having pDCD at baseline and then experiencing change in overweight/obesity status since baseline was associated with changes in self-worth over time (Model 2, Table 4). The interaction term was significant, indicating that the influence of groups on change in self-worth score differs over time and by change overweight/obesity status since baseline. However, it should be noted that the number of children with pDCD who were of healthy body weight at baseline but became overweight/obese over time and number of children with pDCD who were overweight or obese at baseline but lost weight over time to achieve a healthy weight status is small (n=5). Nevertheless, graphs were created from the regression equation generated from model 2 (Table 4) in order to aid in interpretation of the interaction (Figure 1a, Figure1b). It was found that children with pDCD who were not overweight/obese at baseline, but went on to gain weight and were classified as overweight/obese over time had an overall steeper decline in their global self-worth score. Conversely, children with pDCD who were overweight/obese at baseline but achieved a healthy weight status over time had a steeper increase in their global self-worth score. These results suggest that change in overweight/obesity status after 8-9 years (since baseline) has an effect on the rate of change in global self-worth in children with pDCD. In this study, over 50% of the children who were obese at baseline maintained their weight gain for at least 4 waves (half of the follow-up period).

To determine if there is a difference in self-worth between groups and by gender, a two-way interaction between gender and groups was tested and found to be non-significant suggesting that self-worth scores do not differ between boys and girls (results not reported).

### 4.4 Discussion

Previous research has shown an association between DCD and self-worth, and between overweight/obesity and self-worth, but to our knowledge no study has examined the effects of both DCD and overweight/obesity on self-worth. The purpose of the current study was to examine global self-worth at peri-adolescence (ages 8-9) and over time in children having both pDCD and overweight/obesity, only pDCD, and only overweight/obesity. The results of this study showed that children having both conditions (pDCD and overweight/obesity) as well as children having either of these conditions alone reported having lower global self-worth score at baseline compared to typically developing, healthy weight children, and this difference persisted over time. The results also showed that the group to which a child belongs in peri-adolescence has an enduring impact on their self-worth as they age into adolescence.

Our finding that children with only pDCD or only overweight/obesity have lower self-worth score than healthy weight children at baseline is consistent with some previous studies. Several studies have shown that children with DCD have lower global self-worth scores than typically developing children [16-18]. Studies have also shown that overweight and obese children have lower global self-worth than healthy weight children [30, 35]. Therefore, the results of cross-sectional analysis are in agreement with previous findings.

However, this is the first study to show that children with both pDCD and overweight/obesity, as well as children with either of these conditions alone reported lower global self-worth score and the difference in self-worth score between groups remained constant over time. One explanation for this finding may be differences in body image between children having pDCD and/or overweight/obesity and typically developing children with healthy body weight. Generally, there is social pressure on males to be muscular and females to be thinner [46]. Children with pDCD who are overweight or obese deviate from this expectation and therefore they are highly dissatisfied with their body shape, size, and appearance. Body dissatisfaction may lead to negative appraisals of their physical appearance which may in turn explain the low self-worth score reported by this group.

Another explanation for why children with pDCD and overweight/obesity experience lower global self-worth may be due to peer rejection. Adolescents consider social support and approval from friends and classmates as important factors influencing their popularity and social acceptance [18]. Due to poor motor ability and excess body weight, children with pDCD who are overweight or obese may experience lower social acceptance and/or teasing by peers which may have a negative effect on their global self-worth score.

Finally, poor athletic ability may also explain why children with pDCD and overweight/obesity experience lower global self-worth. Children with DCD have poor motor ability so they may perceive themselves to be less competent in athletic activities. In addition, children with DCD also avoid participating in athletic sports due to the fear of failure and ridicule they face from their classmates [47-50]. Moreover, excess body weight may further discourage children with DCD from participating in athletic sports. Participation in physical activity is known to empower individuals and help them achieve their desired body shape, as well as provide opportunities for social interaction and support required for improving global self-worth [51]. Since children with pDCD and overweight/obesity avoid participating in physical activity, they are unable to experience the beneficial effects of physical activity including possible improvement in their self-perceptions.

This study also found a significant three-way interaction term between time, groups, and change in overweight/obesity status since baseline. Graphing this interaction term showed that children with pDCD who were of healthy body weight at baseline but became overweight/obese over time showed a rapid decline in their global self-worth score. Conversely, children with pDCD who were overweight or obese at baseline but lost weight over time to achieve a healthy weight status showed a rapid increase in their global self-worth score. These results suggest that pDCD by weight status groups at baseline does have an effect on the change in global self-worth score over time. However, the number of children in both these groups was very small (n=5) and therefore the proposed interaction should be interpreted with caution.

The strengths of the current study include the longitudinal study design, which allowed us to examine changes in global self-worth score in children over time. In this study, we were able to examine changes in self-worth score in children with both pDCD and overweight/obesity, which has not been examined in previous studies. A limitation of this study is that not all diagnostic criteria for DCD case identification were addressed. DSM IV diagnostic criterion B, interference of motor coordination difficulties with academic achievement and activities of daily living was not addressed in this study.

In conclusion, the results of this study showed that children with both pDCD and overweight/obesity and children with either of these conditions alone report lower global self-worth score at baseline and this difference remains constant over time. Further, weight status of the child at the beginning of the study has an impact on their self-worth score over time as they age. In children with DCD, poor motor ability may not be the only factor affecting their global self-worth. Other factors such as their weight have a negative influence on their global self-worth. Low global self-worth in children is associated with many negative health and social outcomes. Hence, it is important to examine the pathways, which may explain low self-worth score in children so that appropriate interventions can be designed. The lower global self-worth ratings of children with pDCD and overweight/obesity may be explained by negative appraisals of body image, peer rejection, and poor athletic ability. Future studies should examine if these factors play a mediating role in the relationship among global self-worth, DCD and overweight/obesity.

**Table 1: Descriptive characteristics of the participants over the study period**

| | Wave 1 | Wave 2 | Wave 3 | Wave 4 | Wave 5 | Wave 6 | Wave 7 | Wave 8 |
|---|---|---|---|---|---|---|---|---|
| **n** | 2278 | 2228 | 2273 | 2134 | 2141 | 1896 | 1805 | 1581 |
| **Age (yrs), mean (SD)** | 9.9 (0.4) | 10.3 (0.4) | 10.9 (0.3) | 11.3 (0.3) | 11.9 (0.3) | 12.4 (0.3) | 13.4 (0.3) | 14.6 (0.4) |
| **Sex, n (%)** | | | | | | | | |
| **Male** | 1158 (50.8) | 1076 (50.6) | 1083 (51.0) | 1060 (50.5) | 1037 (50.1) | 937 (50.7) | 885 (50.6) | 703 (50.5) |
| **Female** | 1120 (49.2) | 1051 (49.4) | 1042 (49.0) | 1038 (49.5) | 1032 (49.9) | 912 (49.3) | 864 (49.4) | 688 (49.5) |
| **pDCD, n (%)** | 103 (4.5) | 102 (4.6) | 104 (4.6) | 98 (4.6) | 97 (4.5) | 58 (3.1) | 60 (3.3) | 48 (3.0) |
| **BMI ($kg/m^2$), mean (SD)** | | | | | | | | |
| **pDCD** | 21.1 (5.1) | 22.0 (5.1) | 22.4 (5.5) | 22.7 (5.5) | 23.2 (5.6) | 24.6 (5.9) | 25.6 (6.3) | 25.7 (6.3) |
| **No pDCD** | 18.4 (3.4) | 18.8 (3.5) | 19.1 (3.6) | 19.5 (3.9) | 19.9 (3.9) | 20.2 (3.9) | 21.0 (4.0) | 21.5 (4.0) |
| **All** | 18.6 (3.5) | 19.0 (3.7) | 19.2 (3.8) | 19.7 (4.0) | 20.1 (4.0) | 20.3 (4.1) | 21.2 (4.2) | 21.6 (4.2) |
| **Global self-worth score, mean (SD)** | | | | | | | | |
| **pDCD** | 19.0 (4.4) | 18.6 (4.7) | 18.8 (4.6) | 19.0 (4.3) | 19.0 (4.6) | 18.5 (4.6) | 18.3 (4.5) | --- |
| **No pDCD** | 20.2 (3.9) | 20.4 (3.7) | 20.5 (3.7) | 20.5 (3.5) | 20.4 (3.6) | 20.5 (3.5) | 20.1 (3.4) | --- |
| **All** | 20.1 (3.9) | 20.3 (3.8) | 20.4 (3.7) | 20.4 (3.6) | 20.3 (3.7) | 20.4 (3.6) | 20.1 (3.5) | --- |

**Table 2: Proportion of children who are overweight/obese at later time points by groups**

| | DCD and Overweight/obesity | DCD only | Overweight/obesity only | Typical development and healthy body weight |
|---|---|---|---|---|
| **Overweight/obese at later time points (%)** | 90.9 | 15.3 | 82.4 | 8.06 |

**Table 3: Multiple regression model predicting global self-worth score by probable developmental coordination disorder and overweight/obesity status adjusted for age at baseline and gender**

| | Estimate | p-value |
|---|---|---|
| **Intercept** | 25.59 | <.0001 |
| **Gender (Female)** | 0.07 | 0.6843 |
| **Age at baseline (yrs)** | -0.53 | 0.0253 |
| **pDCD and Overweight/obese** | -1.20 | 0.0235 |
| **Only pDCD** | -1.55 | 0.0091 |
| **Only overweight/ obese** | -0.78 | <.0001 |
| **Typical development and healthy body weight** | --- | --- |

**Table 4: Mixed-effects models predicting self-worth score by probable developmental coordination disorder and overweight/obesity status, time, age at baseline, and gender**

| | **Model 1** | | **Model 2** | |
|---|---|---|---|---|
| | **Estimate** | **p-value** | **Estimate** | **p-value** |
| **Intercept** | 21.14 | <.0001 | 21.21 | <.0001 |
| **Gender (Female)** | 0.40 | 0.7568 | $-9.2\times10^{-3}$ | 0.9440 |
| **Age at baseline (yrs)** | -0.39 | 0.0314 | -0.25 | 0.1821 |
| **Groups at baseline** | | | | |
| **Omnibus F-test** | 15.92 | <.0001 | 3.16 | 0.0237 |
| **pDCD and overweight/obese** | -2.01 | <.0001 | -3.00 | 0.0438 |
| **Only pDCD** | -1.39 | 0.0034 | -1.46 | 0.0082 |
| **Only overweight/obese** | -0.77 | <.0001 | -0.53 | 0.1088 |
| **Time (months)** | $-5.3\times10^{-3}$ | 0.0372 | -0.01 | <.0001 |
| **Time*Groups at baseline** | | | | |
| **Omnibus F-test** | 1.14 | 0.3303 | 2.04 | 0.1058 |
| **Time*pDCD and overweight/obese** | 0.01 | 0.4633 | 0.12 | 0.0266 |
| **Time*only pDCD** | 0.02 | 0.1361 | 0.03 | 0.1493 |
| **Time*only overweight/obese** | $5.1\times10^{-3}$ | 0.2978 | $9.0\times10^{-3}$ | 0.4520 |

| | | |
|---|---|---|
| **Overweight/obese at later time points (OWT)** | -0.83 | 0.0024 |
| **OWT*Groups at baseline** | | |
| **Omnibus F-test** | 1.33 | 0.2633 |
| **OWT*pDCD and overweight/obese** | 1.16 | 0.4494 |
| **OWT*only pDCD** | 2.25 | 0.0989 |
| **OWT*only overweight/obese** | 0.49 | 0.2469 |
| **Time*OWT** | 0.02 | 0.0255 |
| **Time *OWT*Groups at baseline** | | |
| **Omnibus F-test** | 3.07 | 0.0268 |
| **Time*pDCD and overweight/obese*OWT** | -0.12 | 0.0416 |
| **Time*only pDCD*OWT** | -0.10 | 0.0588 |
| **Time*only overweight/obese*OWT** | -0.03 | 0.0775 |

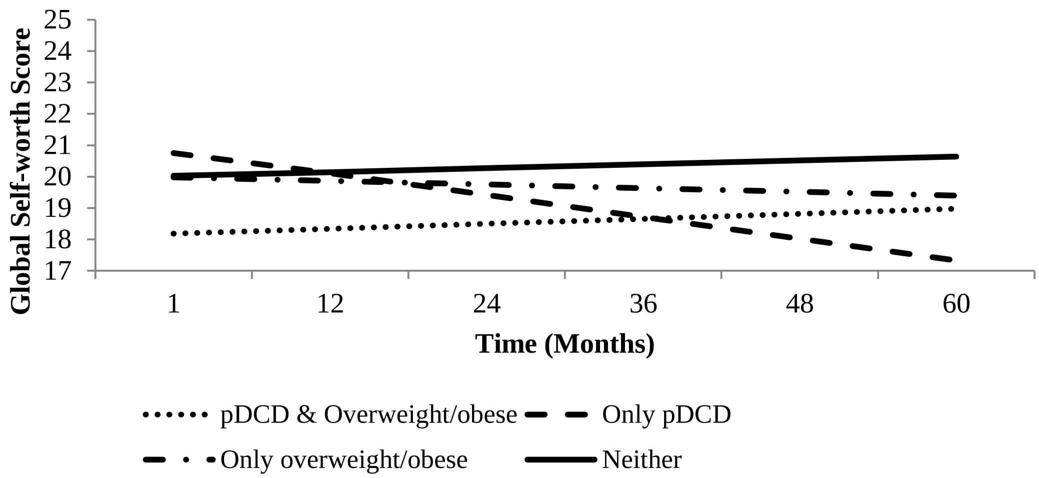


**Figure 1a: Predicted global self-worth by groups (defined at baseline) among children whose weight status remained overweight/obese over time or changed from healthy weight to overweight/obese over time**

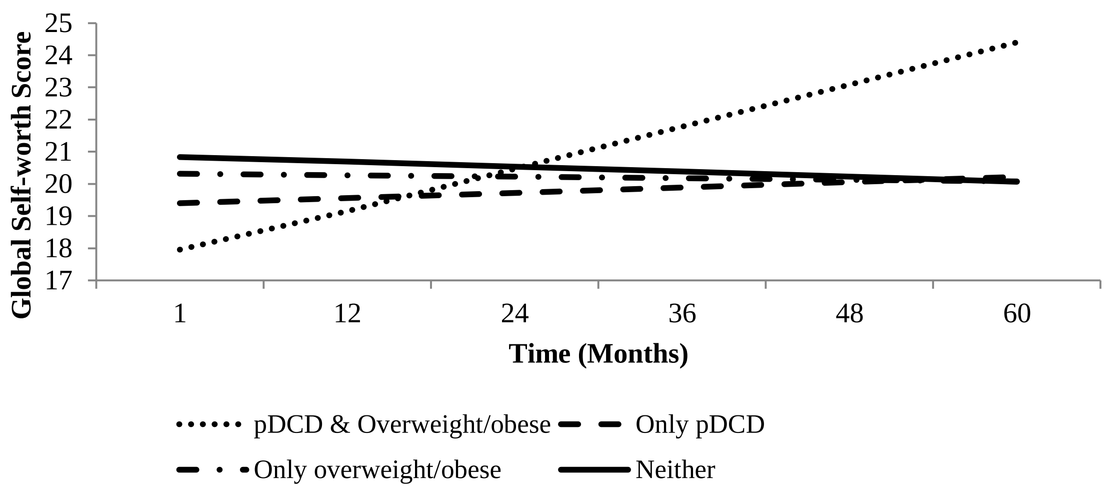


**Figure 1b: Predicted global self-worth by groups (defined at baseline) among children whose weight status remained healthy over time or changed from overweight/obese to healthy weight over time**

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# CHAPTER 5

# DISCUSSION

## 5.1 Overview

This dissertation examined the relationships among pDCD, physical activity, and body composition measures in children over time through completion of three sequential studies. The purpose of the first study was to examine if body composition measures (BMI and waist circumference) in children with pDCD and typically developing children remained constant or varied over time, and whether the sex of the child influenced these patterns of change/stability. Another major objective of this study was to examine if differences in physical activity among typically developing children and children with pDCD explained why children with pDCD were more likely to gain unhealthy body weight.

The second study was conducted to address the inherent limitations of the first study and to obtain a more comprehensive understanding of the relationships among pDCD, physical activity, and body fat. This study examined if differences in percent body fat and BMI between children with pDCD and typically developing children remained constant or varied over time, after adjusting for birth weight and annual household income. Further, the effect of participating in moderate-to-vigorous level physical activity on the relationship between pDCD and body composition measures was also examined.

Having established the pervasiveness of the association between pDCD and overweight/obesity in the first two studies, the purpose of the final study was to examine the combined negative impact of both overweight/obesity and pDCD, first at baseline and then over time, in relation to perceived self-worth. The rationale was that children with *both* poor motor coordination and overweight/obesity may experience a double jeopardy. It was hypothesized that children who have both conditions co-occurring may report lower self-worth compared to children with only one of these conditions, and in comparison with the control group. To date, research has only examined perceived self-worth in children with each of these conditions individually: the compounded problem of pDCD and overweight/obesity has not been examined. This study examined the relationship among global self-worth, pDCD, and overweight/obesity status at baseline after adjusting for age, gender, and overweight/obesity status at later follow-up time points. This relationship was also examined over time to see if aging had any influence on the association among pDCD, body weight status, and self-worth in children.

Together, these three papers form a comprehensive thesis concerning the understanding of the association between pDCD and body composition measures, the possible mechanisms of unhealthy weight gain in children with pDCD, as well as the secondary consequences of unhealthy weight gain in children with pDCD.

## 5.2 Overall Dissertation Findings

The results of these three studies suggest that children with pDCD had higher BMI, waist circumference and percent body fat than typically developing children, and that the difference between groups increased over time for BMI and waist circumference and was maintained over time for percent body fat. These findings are consistent with previous cross-sectional (1-7) and longitudinal studies (8-9) that examined the relationship between DCD and body composition. Unhealthy weight gain in children with pDCD is of concern because it places them at an increased risk of developing obesity-related comorbidities such as metabolic abnormalities, cardiovascular disease, type II diabetes, and poor psychosocial outcomes (10).

Further, the relationship between pDCD and BMI, and between pDCD and waist circumference over time, was found to vary by sex: boys with pDCD had a more rapid increase in BMI and waist circumference than girls with pDCD. This may be related to the onset of a growth spurt and maturational changes occurring in boys with pDCD. Fukunaga and colleagues' study found that maturation had a significant effect on height, weight, and muscle thickness at the abdomen for boys and in muscle thickness at the anterior thigh for girls (11). Another study by Rogol and colleagues found that girls attain peak growth velocity and sexual maturation at an earlier age than boys (12). Early onset of puberty influences growth (height and weight) in children, thereby affecting body composition measures (13). Boys who experienced earlier maturation were taller but had similar body weight compared to their average and late maturing counterparts which resulted in lower BMI scores. This implies that average and late maturing boys were the ones who tended to have higher BMI scores. It is interesting to speculate whether boys with motor delay may experience a more general delay in growth and development (indeed, in some instances a delay in growth and development may affect development of motor coordination (14)). This hypothesis has not been tested in the literature but, based on these findings, should be considered in future research.

The increase in percent body fat was found to be similar between boys and girls with pDCD. The difference in findings between BMI and percent body fat may be due to the fact that BMI is a proxy measure of adiposity and only takes into consideration the weight and height of the child but does not consider changes in fat mass and fat-free mass. In contrast, the percent body fat assessed via BOD POD is a more sensitive measure of adiposity. In typically developing children, some studies have reported sex differences in body fat (15-17), while other studies have found similar amounts of total body fat between boys and girls (18-19). Some studies have also shown that girls typically have more abdominal subcutaneous adipose tissue (15-16), while boys tend to have more visceral adipose tissue during childhood and adolescence (19-21). In the current study, total body fat was examined but the distribution of fat (subcutaneous vs. visceral) was not considered due to the measurement of body fat used. Future studies examining the distribution of fat in children of both sexes may provide a more in depth understanding of the relationship between pDCD and body fat.

Physical activity is an important determinant of overweight and obesity. In the current studies, the effect of physical activity (both self-reported and objectively measured) on the relationship between pDCD and body composition measures was examined to directly test the activity-deficit hypothesis (see Papers 1 and 2). The results of these studies do not lend support to this hypothesis. Rather, the findings of this thesis showed that self-reported physical activity was independently and negatively associated with body composition measures, but did not mediate nor moderate the relationship between pDCD and BMI or between pDCD and waist circumference. Performing a moderate-to-vigorous level of physical activity (accelerometer assessed) also did not have any significant effect on the relationship between pDCD and the percent body fat, or between pDCD and BMI.

There are several possible explanations for these findings. First, the health benefits of physical activity are dependent on the type, intensity, and volume of activity performed by the child. Children tend to participate in short bouts of physical activity and may spend very little time doing vigorous physical activity (22). Baquet and colleagues (22) measured the average length of time, or bout length, in children aged 8-10 years and found that 95% of vigorous intensity physical activity lasted less than 10 seconds per hour. Another study by Sanders and colleagues examined bout length of 14-year old boys and found that the mean length of vigorous physical activity was 3.5 seconds for physical education classes and 2.5 seconds for leisure activities, and that the mean length of moderate physical activity was 2.3 seconds for physical education classes and 2.9 seconds for leisure activities per hour (23). Since the movement patterns in children are more sporadic than those of adults, the use of accelerometers to measure physical activity among children presents some challenges. In the current study, physical activity data was collected in 60-second epochs. However, recent research has suggested that accelerometer assessed physical activity data should be collected in shorter epochs, rather than longer epochs, since shorter epochs are able to record short bursts of physical activity and therefore more moderate-to-vigorous physical activity can be captured (24). Obeid and colleagues (25) found that, in comparison with 3-second epochs, on average 2.9, 9.0, and 16.7 minutes of moderate-to-vigorous physical activity per day was missed when using 15-second, 30-

second, and 60-second epochs, respectively. In another study, using 5-second epochs rather than 60-second epochs resulted in 17 more minutes of moderate-to-vigorous physical activity recorded (26). Results of both these studies illustrate that using short epochs captures more moderate-to-vigorous physical activity but less light and total physical activity. For instance, in one minute, a short burst of physical activity would be categorized as light intensity activity using the 60-second epoch, whereas it would be categorized as 50 seconds of sedentary time and 10 seconds of light or moderate intensity activity using a 10-second epoch. It is possible therefore that the current study may have misclassified the intensity of physical activity in children. Hence, future studies should use shorter epoch lengths such as 3-second or 1-second in order to accurately measure the intensity of physical activity in children.

Despite limitations in measuring physical activity, overall, the activity-deficit hypothesis may be too simple and inadequate to explain the complex relationship between pDCD and body composition. A more multi-factorial approach, considering the multiple determinants of risk and protective factors is likely to prove more useful for future research. For example, a model including growth, stress, and diet, besides physical activity should be considered when explaining the differences in body composition between groups. It is known that excessive food intake is associated with overweight and obesity. Body weight cannot change when energy intake and energy output are equal. An imbalance in the energy intake and output, when intake is in excess of output, is known to contribute to increased body weight. According to Hill and Commerford (27), positive energy balance occurs when energy intake is greater than energy expenditure, which results in an increase in body weight, 60-80% of which is usually body fat. Conversely, a negative energy balance occurs when energy expenditure is greater than energy intake, which results in loss of body weight. No studies have explored whether differences in energy intake (diet) differ between children with DCD and those without. Although it is not entirely clear why children with DCD may be more likely to consume increased calories, a possible explanation may be the stress experienced as a result of the disorder.

Cairney and colleagues (28) proposed the environment-stress hypothesis, which posits that DCD acts as a primary stressor, affecting a whole set of interpersonal and social factors, which in turn influences health and well-being. Children with DCD who have a motor impairment are more likely to experience negative interpersonal and psychosocial consequences such as social isolation, being teased, bullied, and ridiculed, and lower social competence and self-esteem, which in turn may lead to internalizing problems such as increased distress, anxiety, and depression (28). Research suggests that individuals may modify their eating behaviours when they perceive themselves to be stressed (29). Modification of eating behaviours occurs in two ways – under-eating or overeating, and may be influenced by the severity of the stressor (30). It has been found that chronic stress is associated with preference for energy-dense foods, particularly foods that are high in fat and sugar and may therefore be associated with increased weight gain (30). In children, stress has been positively correlated with unhealthy eating behaviours, increased weight gain, and use of eating as a mechanism to cope with stress (31-33). A study by Zellner and colleagues found that individuals reporting increased stress changed their food choices from low fat foods to high fat foods (34). Since children with DCD experience chronic stress, it can be hypothesized that they may have a higher energy intake, which may explain why they are more likely to have higher BMI, waist circumference, and percent body fat than typically developing children. So far, no study has examined this pathway in children with DCD and typically developing children. Future studies should examine the role of environment-stress hypothesis and dietary intake and nutrition when explaining excess weight gain in children with DCD. Exploring these factors are also necessary so that intervention programs can be designed to address the problem of unhealthy weight gain in children with DCD.

Given the robustness of the findings concerning obesity in children with pDCD, the study in Chapter 4 was an attempt to begin to better understand the combined effects of both poor motor coordination and overweight/obesity in relation to global self-worth at baseline and over time. The results showed that children who have both conditions, as well as children having either of these conditions alone, reported having lower global self-worth at baseline compared to typically developing, healthy weight children. The difference in self-worth between groups was maintained over time. These results suggest that, in addition to motor ability, children's weight status at peri-adolescence may also have a lasting impact on their self-worth as they progress into adolescence. Based on the literature, it can be hypothesized that the difference in perceived self-worth between groups may be explained by children's self-perceptions of physical appearance (35-37), social competence (35, 38), or athletic competence (37-42). However, to date, no studies have examined these pathways. These results may also be linked to the environment-stress hypothesis (28). As discussed above, results have shown that both pDCD and overweight/obesity negatively impact self-worth. Further, it can be hypothesized that children with lower self-worth may not be able to cope with stress effectively. Examining these associations in future studies of children and adolescents will help us better understand the complex relationship among DCD, overweight/obesity, and self-worth.

### 5.3 Study Strengths and Limitations

A major strength of the studies is the longitudinal study design that allowed for examining trajectories of change in BMI, waist circumference, percent body fat, and self-worth over time. Also, the PHAST study recruited a population-based sample, which reduces concerns related to clinical-referral bias. Finally, it is important to comment on the sample size and attrition rate during the five-year follow-up period. Sample size data presented in Appendix I gives the impression that the attrition rate by the end of the follow-up period was high, however, data presented in Appendix II show that the retention rate of participants for at least five waves (over half of the follow-up period) is 72.3%, which is considered to be fairly good. This means that although the attrition rate may be high, children who were loss-to-follow-up had provided data for multiple time points to contribute to the slope estimates. The primary reason for loss-to-follow-up was that upon completing elementary school, children switched schools to attend a high school under a different school board that was not part of our study. This resulted in an abrupt loss of participants seen at wave 6. However, mixed-effects modeling technique used to analyze the data has accommodated for imbalanced data or missing values for the response variable. Therefore, the overall sample size can be considered to be large, which ensured adequate study power to examine the research questions.

A major limitation is that the effect of motor coordination on children's academic achievement and activities of daily living was not assessed in these studies. This may have resulted in an overestimation of the pDCD cases. Another limitation is that the epoch length of accelerometer-assessed physical activity was relatively longer (60 seconds compared to 1 second), which may have misclassified the intensity of physical activity in children.

### 5.4 Implications and Future Directions

There is evidence suggesting that children with pDCD are more likely to be overweight or obese. Overweight/obesity and physically inactivity is associated with a greater risk for chronic diseases including metabolic abnormalities, and poor cardiovascular and psychosocial outcomes in all children (10). Thus, future studies should examine the long-term consequences of poor motor ability, physical inactivity, and obesity on metabolic, cardiovascular, and psychosocial outcomes in children with DCD. One challenge in examining the relationship between poor motor coordination and body composition is the accurate assessment of physical activity. It is recommended that, when measuring accelerometery, future studies use a shorter epoch length to accurately measure the intensity of physical activity. Using a self-reported questionnaire along with accelerometers will provide a more comprehensive assessment of physical activity in children. Results from the studies discussed in earlier chapters also indicate that the activity-deficit hypothesis may not adequately explain the differences in body composition between groups. Therefore, in addition to physical activity, the role of other factors such as the environment-stress hypothesis (chronic stress as a result of DCD) and diet should be examined to see if they explain why children with DCD are more likely to be overweight or obese. Identification of these factors is important so that parents and health professionals working with children affected by DCD can target these factors when designing interventions to address problems of overweight and obesity.

The study discussed in Chapter 4 found consistently lower self-worth in children with pDCD who also had overweight/obesity. However, the mechanisms for this relationship were unclear. Future studies should investigate if the lower global self-worth ratings of children with pDCD and overweight/obesity may be explained by negative appraisals of body image, peer rejection, and/or poor athletic ability. Lower self-worth in children is of concern because it is associated with negative consequences including body dissatisfaction, eating disorders, peer victimization, anxiety, and depression, which, in turn, are associated with poor health outcomes (43-48). Therefore, identification of factors that explain low self-worth in children with DCD and overweight/obesity is important in order to improve self-worth and prevent negative consequences of low self-worth. The study examined the consequences of pDCD and overweight/obesity on a single psychological outcome (global self-worth). Future studies should also examine the effects of pDCD and overweight/obesity on other psychosocial outcomes such as depression. Finally, intervention studies targeted at improving motor skills will also be useful in addressing the problem of overweight and low self-worth in children.

### 5.5 Final Conclusions

In conclusion, children with pDCD were found to have higher BMI, waist circumference, and percent body fat than typically developing children, and this difference increased over time for BMI and waist circumference and was maintained over time for percent body fat. Boys with pDCD were found to have a more rapid increase in BMI and waist circumference when compared with girls with pDCD; however, there were no significant differences in percent body fat between the sexes. Regardless of the type of measure used (self-report vs. objectively assessed), physical activity did not explain differences in body composition measures between groups. Participation in physical activity was independently and negatively associated with body composition. Further, children with both probable DCD and overweight/obesity reported lower self-worth at baseline when compared with typically developing-healthy weight children and this difference was maintained over time as children aged into adolescence.

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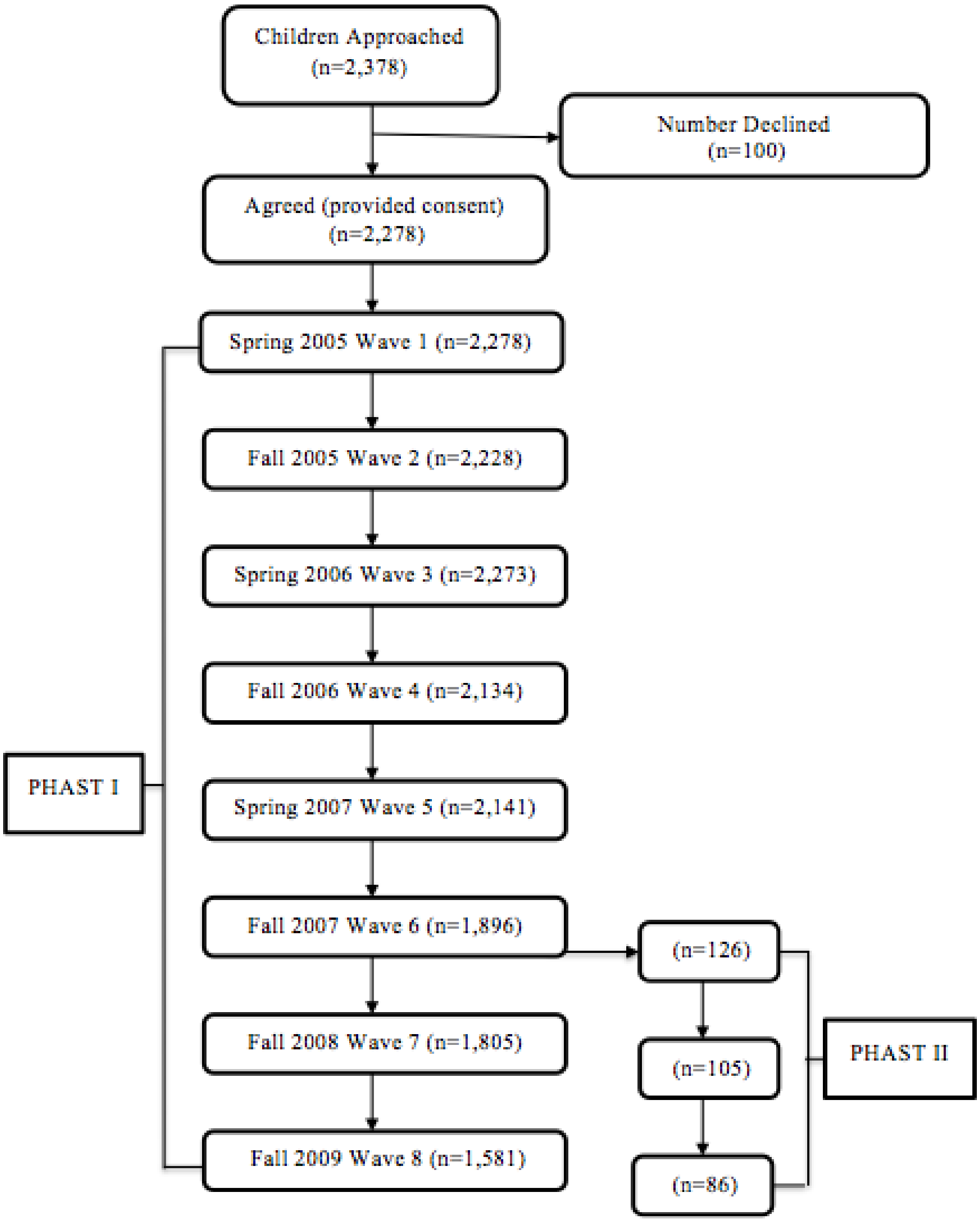
## Appendix I

### Flow of Participants in PHAST I and II Study




Note 1: Reasons for loss to follow-up: Graduated and moved to middle/high school, left participating school, or withheld consent

Note 2: PHAST was an open cohort so participants were added to the study as it went on

## Appendix II

### Retention of Participants over Multiple Waves

| Wave | Percentage of Participants (%) |
|---|---|
| At least 1 | 100.00 |
| At least 2 | 93.46 |
| At least 3 | 89.00 |
| At least 4 | 74.16 |
| At least 5 | 72.33 |
| At least 6 | 51.57 |
| At least 7 | 48.05 |
| At least 8 | 36.49 |

# Appendix III

## PARTICIPATION QUESTIONNAIRE - ELEMENTARY

Name: ___________________________ Age: ______ years

Grade: __________ Do you take Physical Education classes? YES / NO

**INSTRUCTIONS:**

In this survey you will be asked about the activities that you do at school and in your spare time. There are no right or wrong answers because this is not a test! Just answer each question as best as you can remember. Please read each question carefully before you answer it. TO ANSWER A QUESTION, JUST CHECK (✓) YOUR ANSWER OR PRINT YOUR ANSWER IN THE SPACE PROVIDED. Only select one answer for each question.

The following is a sample question to practice.

**SAMPLE QUESTION**

**1. How often do you eat an apple?**

| Never | Once a month | Once a week | Once a day |
|---|---|---|---|
| 0 | 0 | 0 | 0 |

**SECTION 1: FREE TIME ACTIVITIES**

This section asks questions about what you do during your free time. Some of the questions will be about recess, some about what you like to do after school, and others will be about what you do on weekends and holidays. Active games mean things like tag or skipping or playing catch.

**1. During recess (or spares), do you spend most of your time:**

| Talk with my friends | Do school work | Play active games |
|---|---|---|
| ❑ | ❑ | ❑ |

**2. After school and before you eat supper, most of the time do you:**

| Watch television | Talk with my friends | Play active games | Play video games | Do other things (Specify below) |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | ______ |

**3. After supper and before you go to bed, do you spend most of your time:**

| Watch television | Talk with my friends | Read books | Play active games | Do other things (Specify below) |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | ______ |

**4. On weekends, do you spend most of your time:**

| Watch television | Read | Play active games | Play video games | Talk with my friends | Do other things (Specify below) |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | ______ |

**5. During your free time, what are the three (3) things you like to do the most?**

1. ______ 2. ______ 3. ______

**6. During the summer, how often do you ride a bike? (If you answer never, go to Question #8)**

| Never | Once a month | Once a week | Once a day | All the time |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

**7. When you finish riding your bike, do you usually feel:**

| Very tired | Tired | A little tired | Not tired at all |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**8. During the winter, how often do you go ice skating for fun? (If you answer never, go to Question #10)**

| Never | Once a month | Once a week | Once a day | All the time |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

**9. When you finish ice skating, do you usually feel:**

| Very tired | Tired | A little tired | Not tired at all |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**10. How often do you go swimming for fun during the summer? (If you answer never, go to Question #12)**

| Never | Once a month | Once a week | Once a day | All the time |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

**11. When you have finished swimming, do you usually feel:**

| Very tired | Tired | A little tired | Not tired at all |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**12. During the winter, how often do you go cross-country skiing? (If you answer never, go to Question #14)**

| Never | Once a month | Once a week | Once a day | All the time |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

**13. When you finish cross-country skiing, are you usually:**

| Very tired | Tired | A little tired | Not tired at all |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**14. If there are other activities that you do once a week or more, please list them below:**

1. ____________________ 2. ____________________ 3. ____________________

**15. How often do you watch television?**

| Every day | Almost every day | Hardly ever | Never |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**16. How many hours per day do you usually watch television?**

| 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**17. How often do you read a book in your free time?**

| Every day | Almost every day | Hardly ever | Never |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**18. How many hours a day do you usually read books?**

| 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**19. How often do you play video games in your spare time?**

| Every day | Almost every day | Hardly ever | Never |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**20. How often do you play active games with your friends after school?**

| 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**21. How often in a week do you play active games with your family?**

| Every day | Almost every day | Hardly ever | Never |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**22. When you are playing active games with your friends or family, how often do you play hard enough to breathe heavily or make your heart beat quickly?**

| Very often | Often | Sometimes | Hardly ever | Never |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

**23. If you have daily or weekly chores at home (cutting grass, shoveling snow, farm chores, paper route), please list them below.**

1. ____________________ 2. ____________________ 3. ____________________

**24. How do you usually get to school?**

| Walk | Ride a bike | Take the bus | Get a ride |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**25. How long does it take you to get to school?**

| 0-15 minutes | 15-45 minutes | more than 45 minutes |
|---|---|---|
| ❑ | ❑ | ❑ |

**26. How many older brothers do you have?** ______________

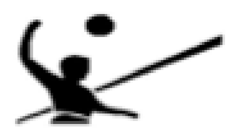
**27. How many older sisters do you have?** ______________

**28. How many younger brothers do you have?** ______________

**29. How many younger sisters do you have?** ______________

## SECTION 2: INTRAMURAL or HOUSE LEAGUE GAMES

. These are games like borden ball or volleyball that you play in teams at school. Only include active games. These do not include games you play in physical education classes, or recesses. **If you haven't played any intramural games this year, check this box ❑ and go directly to SECTION 3.**



**30. How many different intramural (house-league) activities have you played this school year?**

| 0 | 1 | 2 | 3 | 4 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**(If you answered 0, please go directly to SECTION 3)**

**31. During your intramural games, how often did you have to work hard (breathing heavily, sweating, heart beating quickly):**

| Very often | Often | Sometimes | Hardly ever | Never |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

**32. After playing games in intramurals, are you usually:**

| Very tired | Tired | A little tired | Not tired at all |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**33. How many times a week, on average, do you play intramural games?**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 or more |
| 0 | 0 | 0 | 0 | 0 | 0 |

**34. How many hours each week do you think you spend playing intramural games at school?**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 or more |
| 0 | 0 | 0 | 0 | 0 | 0 |

**35. How many of your friends play intramural games?**

| | | |
|---|---|---|
| Most of them ❑ | A few of them ❑ | None of them ❑ |

## SECTION 3: SCHOOL SPORTS TEAMS

These questions are about school teams that play sports against teams from other schools. **If you don't play for any of your school's sports teams, check this box ❑ and go directly to SECTION 4.**

**36. This school year, how many school sports teams have you belonged to?**

| | | | | |
|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 |
| 0 | 0 | 0 | 0 | 0 |

**(If you answered 0, please go directly to SECTION 4)**

**37. After a game or practice, are you usually:**

| | | | |
|---|---|---|---|
| Very tired ❑ | Tired ❑ | A little tired ❑ | Not tired at all ❑ |

**38. During games or practices, did you have to work hard (breathing heavily, sweating, heart beating quickly):**

| | | | | |
|---|---|---|---|---|
| Very often | Often | Sometimes | Hardly ever | Never |
| 0 | 0 | 0 | 0 | 0 |

**39. How many hours per week do you usually spend in practices or games for school sports teams?**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 or more |
| 0 | 0 | 0 | 0 | 0 | 0 |

**40. How many of your friends play on school sports teams?**

| | | |
|---|---|---|
| Most of them ❑ | A few of them ❑ | None of them ❑ |

**SECTION 4: SPORTS TEAMS OUTSIDE OF SCHOOL**

These are teams like hockey, ringette, soccer, and baseball in leagues that are not part of your school. **If you haven't played on any sports teams in the last year, check this box ❑ and go directly to SECTION 5.**

**41. In the last year, how many sports teams have you played on?**

| 0 | 1 | 2 | 3 | 4 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**If you answered 0, go directly to SECTION 5)**

**42. How many times a week, on average, do you go to a practice or game?**

| 0 | 1 | 2 | 3 | 4 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**43. How many hours a week, on average, do you think you spend at practices and playing games for sports teams?**

| 0 | 1 | 2 | 3 | 4 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**44. During games and practices, did you have to work hard (breathing heavily, sweating, heart beating quickly):**

| Very often | Often | Sometimes | Hardly ever | Never |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

**45. After a practice or game, did you usually feel:**

| Very tired | Tired | A little tired | Not tired at all |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**46. How many of your friends play on sports teams?**

| Most of them | A few of them | None of them |
|---|---|---|
| ❑ | ❑ | ❑ |

0 0 0 0 0

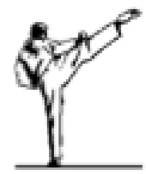
**52. How tired to you feel after a sport or dance competition or practice?**

| Very tired | Tired | A little tired | Not tired at all |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**53. How many of your friends belong to sports or dance clubs?**

| Most of them | A few of them | None of them |
|---|---|---|
| ❑ | ❑ | ❑ |

## SECTION 5: SPORTS AND DANCE CLUBS



These are clubs like gymnastics, martial arts (karate, judo, etc.), tennis, golf, swimming, horseback riding, and dance (jazz, ballet, and tap). It <u>doesn't</u> include groups like Cubs or Girl Guides or 4H. **If you didn't belong to any sports or dance clubs in the last year, check this box ❑ and go directly to SECTION 6**

**47. In the last <u>year</u>, how many DANCE clubs have you belonged to?**

| 0 | 1 | 2 | 3 | 4 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**48. In the last <u>year</u>, how many SPORTS clubs did you belong to?**

| 0 | 1 | 2 | 3 | 4 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**49. How many <u>times a week</u>, on average, do you go to a sport or dance competition or practice?**

| 0 | 1 | 2 | 3 | 4 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**50. How many <u>hours a week</u>, on average, do you think you spend at sport or dance activities?**

| 0 | 1 | 2 | 3 | 4 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**51. During practices or competitions, how often did you have to work hard (breathing heavily, sweating, heart beating quickly):**

| Very often | Often | Sometimes | Hardly ever | Never |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

**52. How tired to you feel after a sport or dance competition or practice?**

| Very tired | Tired | A little tired | Not tired at all |
|---|---|---|---|
| ❑ | ❑ | ❑ | ❑ |

**53. How many of your friends belong to sports or dance clubs?**

| Most of them | A few of them | None of them |
|---|---|---|
| ❑ | ❑ | ❑ |

## SECTION 6: SPORTS AND DANCE LESSONS

This section asks questions about lessons that you took in the last year to learn things like swimming, tennis, golf, or dance. It also includes hockey schools. It doesn't include practices for teams or clubs. If you didn't take any sport or dance lesson in the last year, check this box ❑ and go directly to SECTION 7.

**54. In the last year, how many different kinds of sports or dance lessons did you take?**

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 or more |

**(If you answered 0, go directly to SECTION 7)**

**55. How many hours a week, on average, did you spend at sport or dance lessons?**

| 0 | 1 | 2 | 3 | 4 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**56. How many times a week did you go to a sport or dance lesson?**

| 0 | 1 | 2 | 3 | 4 | 5 or more |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |

**57. How many of your friends take sport or dance lessons?**

| Most of them | A few of them | None of them |
|---|---|---|
| ❑ | ❑ | ❑ |

**58. During your sport or dance lessons, how often did you have to work hard (breathing heavily, sweating, and heart beating quickly):**

| Very often | Often | Sometimes | Hardly ever | Never |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |

## SECTION 7: UNDERSTANDING YOUR BODY

This section asks questions that will help us learn how much you understand about your body composition.

**59.I think I weigh ______ pounds.**

**60.I think I am ______ feet_____ inches tall.**

**61.Check the answer that best describes how you feel about your body.**

| | | | | |
|---|---|---|---|---|
| Very underweight | Somewhat underweight | Just the right weight | Somewhat overweight | Very overweight |
| 0 | 0 | 0 | 0 | 0 |

**62. Check the answer that best describes how you would change your body.**

| | | | | |
|---|---|---|---|---|
| Lose a lot of weight | Lose a little weight | Stay the same | Gain a little weight | Gain a lot of weight |
| 0 | 0 | 0 | 0 | 0 |

**63. Check the answer that best describes how you like the way your body looks.**

| | | | |
|---|---|---|---|
| A lot | A little | Not at all | Hate how I look |
| ❑ | ❑ | ❑ | ❑ |

**THANK YOU VERY MUCH FOR COMPLETING THE PARTICIPATION QUESTIONNAIRE!** ☺

## Appendix IV

## HARTER SCALE: WHAT I AM LIKE!

Take your time and do the whole form carefully. Remember to only check one box on the side that has the sentence most like you. If you have any questions just ask!

| REALLY TRUE for me | SORT OF TRUE for me | | | | SORT OF TRUE for me | REALLY TRUE for me |
|---|---|---|---|---|---|---|
| ❑ | ❑ | Some teenagers feel that they are just as smart as others their age. | **BUT** | Other teenagers aren't so sure and wonder if they are as smart. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers find it hard to make friends. | **BUT** | For other teenagers it's pretty easy. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers do very well at all kinds of sports. | **BUT** | Other teenagers don't feel that they are very good when it comes to sports. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers are not happy with the way they look. | **BUT** | Other teenagers are happy with the way they look. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers feel that they are ready to do well at a part-time job. | **BUT** | Other teenagers feel that they are not quite ready to handle a part-time job. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers feel that if they are romantically interested in someone, that person will like them back. | **BUT** | Other teenagers worry that when they like someone romantically, that person won't like them back. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers usually do the right thing. | **BUT** | Other teenagers often don't do what they know is right. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers are able to make really close friends. | **BUT** | Other teenagers find it hard to make really close friends. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers are often disappointed with themselves. | **BUT** | Other teenagers are pretty pleased with themselves. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers are pretty slow in finishing their school work. | **BUT** | Other teenagers can do their school work more quickly. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers have a lot of friends. | **BUT** | Other teenagers don't have very many friends. | ❑ | ❑ |

| REALLY TRUE for me | SORT OF TRUE for me | | | | SORT OF TRUE for me | REALLY TRUE for me |
|---|---|---|---|---|---|---|
| ❑ | ❑ | Some teenagers think they could do well at just about any new athletic activity. | **BUT** | Other teenagers are afraid they might not do well at a new athletic activity. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers wish their body was different | **BUT** | Other teenagers like their body the way it is. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers feel that they don't have enough skills to do well at a job. | **BUT** | Other teenagers feel that they do have enough skills to do a job well. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers are not dating the people they are really attracted to. | **BUT** | Other teenagers are dating those people they are attracted to. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers often get in trouble for the things they do. | **BUT** | Other teenagers usually don't do things that get them in trouble. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers do have a close friend they can share secrets with. | **BUT** | Other teenagers do not have a really close friend they can share secrets with. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers don't like the way they are leading their life. | **BUT** | Other teenagers do like the way they are leading their life. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers do very well at their classwork. | **BUT** | Other teenagers don't do very well at their classwork. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers are very hard to like. | **BUT** | Other teenagers are really easy to like. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers feel that they are better than others their age at sports. | **BUT** | Other teenagers don't feel they can play as well. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers wish their physical appearance was different. | **BUT** | Other teenagers like their physical appearance the way it is. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers feel they are old enough to get and keep a paying job. | **BUT** | Other teenagers do not feel they are old enough, yet, to really handle a job well. | ❑ | ❑ |

| REALLY TRUE for me | SORT OF TRUE for me | | | | SORT OF TRUE for me | REALLY TRUE for me |
|---|---|---|---|---|---|---|
| ❑ | ❑ | Some teenagers feel that people their age will be romantically attracted to them. | **BUT** | Other teenagers worry about whether people their age will be attracted to them. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers feel really good about the way they act. | **BUT** | Other teenagers don't feel that good about the way they often act. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers wish they had a really close friend to share things with | **BUT** | Other teenagers do have a close friend to share things with. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers are happy with themselves most of the time. | **BUT** | Other teenagers are often not happy with themselves. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers have trouble figuring out the answers in school. | **BUT** | Other teenagers almost always can figure out the answers. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers are popular with others their age. | **BUT** | Other teenagers are not very popular. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers don't do well at new outdoor games. | **BUT** | Other teenagers are good at new games right away. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers think that they are good looking. | **BUT** | Other teenagers think that they are not very good looking. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers feel like they could do better at work they do for pay. | **BUT** | Other teenagers feel that they are doing really well at work they do for pay. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers feel that they are fun and interesting on a date. | **BUT** | Other teenagers wonder about how fun and interesting they are on a date. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers do things they know they shouldn't do. | **BUT** | Other teenagers hardly ever do things they know they shouldn't do. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers find it hard to make friends they can really trust. | **BUT** | Other teenagers are able to make close friends they can really trust. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers like the kind of person they are. | **BUT** | Other teenagers wish they were someone else. | ❑ | ❑ |

| REALLY TRUE for me | SORT OF TRUE for me | | | | SORT OF TRUE for me | REALLY TRUE for me |
|---|---|---|---|---|---|---|
| ❑ | ❑ | Some teenagers feel that they are pretty intelligent. | BUT | Other teenagers question whether they are intelligent. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers feel that they are socially accepted. | BUT | Other teenagers wished that more people their age accepted them. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers do not feel that they are very athletic. | BUT | Other teenagers feel that they are very athletic. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers really like their looks. | BUT | Other teenagers wish they looked different. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers feel that they are really able to handle the work on a paying job. | BUT | Other teenagers wonder if they are really doing as good a job at work as they should be doing. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers usually don't go out with the people they would really like to date. | BUT | Other teenagers do go out with the people they really want to date. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers usually act the way they know they are supposed to. | BUT | Other teenagers often don't act the way they are supposed to. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers don't have a friend that is close enough to share really personal thoughts with. | BUT | Other teenagers do have a close friend that they can share personal thoughts and feelings with. | ❑ | ❑ |
| ❑ | ❑ | Some teenagers are very happy being the way they are. | BUT | Other teenagers wish they were different. | ❑ | ❑ |

THANK YOU VERY MUCH FOR COMPLETING THIS SCALE! ☺

## Appendix V

## Ethics Approval and Renewal

**DATE:** March 24, 2004

**FROM:** Joe Engemann, Chair
Senate Research Ethics Board (REB)

**TO:** John Hay, Community Health Sciences
John Cairney, Community Health Sciences
Brent Faught, Community Health Sciences
Karen Calzonetti, Physical Education and Kinesiology
James Mandigo, Physical Education and Kinesiology
Frances Owen, Child and Youth Studies

**FILE:** 03-342 Hay/Cairney/Faught/Calzonetti/Mandigo/Owen

**TITLE**: Developmental Coordination Disorder: Examination of a Feasible Screening and Intervention for Clumsy Children

The Brock University Research Ethics Board has reviewed the above research proposal.

**DECISION:** Accepted as Clarified

This project has been approved for the period of **March 24, 2004** to **June 30, 2007** subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The approval may be extended upon request. ***The study may now proceed.***

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed and approved by the REB. The Board must approve any modifications before they can be implemented. If you wish to modify your research project, please refer to www.BrockU.CA/researchservices/forms.html to complete the appropriate form ***REB-03 (2001) Request for Clearance of a Revision or Modification to an Ongoing Application.***

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants and the continuation of the protocol. If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research protocols. The Tri-Council. Policy Statement requires that ongoing research be monitored. A Final Report is required for all projects, with the exception of undergraduate projects, upon completion of the project. Researchers with projects lasting more than one year are required to submit a Continuing Review Report annually. The Office of Research Services will contact you when this form ***REB-02 (2001) Continuing Review/Final Report*** is required. Please quote your REB file number on all future correspondence.

Deborah VanOosten, Research Ethics Officer
*Brock University*
*Office of Research Services*
*500 Glenridge Avenue*
*St. Catharines, Ontario, Canada L2S 3A1*
phone: (905)688-5550, ext. 3035 fax: (905)688-0748
email: deborah.vanoosten@brocku.ca
http://www.brocku.ca/researchservices/humanethics.html

FROM: Michelle McGinn, Chair
Research Ethics Board (REB)

TO: J. Hay, AHS-Community Health Sciences
Cairney, J., Faught, B., Calzonetti, K., Mandigo, J., Owen, F.

RE: Continuing Review

FILE: 03-342 - Hay
Faculty Research
Original clearance date: March 24, 2004
Date of completion: December 31, 2009

DATE: February 26, 2009

---

Thank you for completing the ***Continuing Review*** form***.*** The Brock University Research Ethics Board has reviewed this report for:

***Developmental Coordination Disorder: Examination of a Feasible Screening and Intervention for Clumsy Children***

The Committee finds that your original proposal and ongoing research conforms to the Brock University guidelines set out for ethical research.

*** Continuing Review Accepted.**

MM/an

Research Ethics Office
Brock University
Office of Research Services, MC D250A
500 Glenridge Avenue, St. Catharines, ON L2S 3A1
Phone 905-688-5550 ext. 3035
Fax 905-688-0748
Email: reb@brocku.ca
http:/www.brocku.ca/researchservices/Ethics_Safety/Humans/Index.php

FROM: Michelle McGinn, Chair
Research Ethics Board (REB)

TO: Brent FAUGHT, CHSC
John Hay

RE: Continuing Review

FILE: 07-106 - FAUGHT
Faculty Research
Original clearance date: January 10, 2008
Date of completion: December 30, 2012

DATE: April 13, 2010

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Thank you for completing the ***Continuing Review*** form**.** The Brock University Research Ethics Board has reviewed this report for:

***Establishing the Health Profile of Children with Motor Coordination Challenges***

The Committee finds that your original proposal and ongoing research conforms to the Brock University guidelines set out for ethical research.

*** Continuing Review Accepted.**

MM/sp

**Research Ethics Office**
Brock University | Brock Research
Niagara Region | 500 Glenridge Ave. | St. Catharines, ON L2S 3A1
brocku.ca | T 905 688 5550 x3035 | F 905 688 0748

## Appendix VI

## PHAST – Phase 1 Informed Consent Form for School Assessments

### LETTER OF INFORMED CONSENT

Physical Fitness Activity and Movement Research - Brock University

Principal Investigator: Dr. John Hay, Department of Community Health Sciences

Dear
Parents/Guardians:
Brock University researchers are conducting a study to investigate the factors associated with the physical activity of children. These factors include a child's confidence and enjoyment in being active, their movement ability, and their physical fitness. Not all children are athletes and many children have difficulty in performing physical activities. Sometimes the difficulties that children have with being active create challenges for them in school.

We would like to see if we can provide information to teachers and parents that will help all children learn to enjoy being physically active. Classroom appraisals that form part of the usual physical education program in school can be used to help parents and teachers guide suggestions to improve physical activity. Unfortunately these appraisals are very expensive to carry out and schools are usually not able to fund them. Funding provided by the Government of Canada for this research will allow schools in the District School Board of Niagara to provide these appraisals to students in Grade Four and again in Grades Five, and Six.

The study will be conducted over this 3-year period and requires the involvement of parents, teachers, and most importantly children. Students will take part in fitness appraisals and complete three questionnaires about physical activity. Students will also take part in movement skill appraisals. These appraisals and questionnaires support the Ontario Health and Physical Education curriculum for elementary school students. For each child in the study, we will provide an appraisal report and a resource package to parents and teachers to help understand the results of the appraisals and to provide suggestions that could help promote physical activity. If you do not provide consent your child will still participate with the rest of the class in these appraisals, but their results will not be used by Brock University. The different appraisals are described below. Trained university personnel will carry out all testing.

**Fitness Appraisal**
The 20-meter shuttle run for fitness will take place during physical education classes. Students run 20 metre lengths in time to a recording until they cannot keep up with the

recording. It lasts less than five minutes but is tiring. Body composition (muscle, bone, and fat) will be measured using height, weight and bioelectrical impedance. Bioelectrical impedance requires a microelectronic current to go from small sensors placed on the wrist and ankle for two seconds. There is absolutely no danger involved as this current is tiny and students will not feel it – many new bathroom scales use the same technology but are not as accurate. The sensors are equivalent to small bandages (2cmX4cm) that are connected to a single thin wire. The procedure is completely safe and painless.

**The Questionnaires**

The questionnaires ask about your child's activities during both their free time and in organized activities, as well as their attitudes toward physical activity. There are no questions that deal with private or personal matters. A sample question is: "Do you enjoy playing active games outside?" Each questionnaire will be carried out in the classroom and they can all be completed within 30 minutes.

**Movement Skill Appraisal**

The movement skills appraisal is done individually and looks at things like balance, ball catching, jumping, and drawing shapes. It takes about 20 minutes and presents no physical danger – in previous studies, students have found it fun to do.

We will also be following your child's school grades and provincial test results to see if there is any relationship with school performance and changes in your child's participation and enjoyment of physical activity over the three years. Any information we receive will be entered into computer records using a code number with no name attached. All the information we collect will be kept absolutely confidential when being reported. We will only present the results of multiple schools, so that no single child, family, or school will be able to be identified. When the study is complete, a summary report on the findings will be available to interested parents at your school's main office.

There will be no effect on your child's school evaluation if their results are not entered in this project. Your child's participation is voluntary and he/she may withdraw from the study at any time. There is no obligation for your child to answer any questions nor to participate in any aspect of this project.

All personal data will be kept strictly confidential and all information will be coded so that your child's name is not associated with his/her answers. Only the researchers named above will have access to the data. It is our intent to publish the results of this research in scientific journals. Again, no personal information regarding your child, school or school board will be identified within the publication.

This study has been reviewed and approved by the Brock University Research Ethics Board, (File #: 03-342) Research Services, Brock University, Room C315 - 905-688-

5550 (Ext. 4315) and has been approved by the Research Committee of the District School Board of Niagara.

I greatly appreciate your co-operation. If you would like to receive more information about the study, review the questionnaires, or learn more about any of the appraisals, please contact Dr. John Hay at 905-688-5550, (Ext. 4017).

The consent form below is to allow our research team to use the data from the fitness appraisal, questionnaire and movement appraisal activities. If you do not provide consent your child will still participate with the rest of the class in these appraisals, but their results will not be used by Brock University. Please complete the consent form below and have your child return it to their teacher before November 11, 2004.

Thank you for your

help!

John A. Hay, Ph.D.

**LETTER OF INFORMED CONSENT**

Physical Fitness Activity and Movement Research
Brock University, Community Health Sciences

Parental/Guardian Statement:

I hereby certify that I am the parent or legal guardian of the student named above, who is under the age of 18 years.

The fitness and movement appraisals are regular physical education tasks that meet the expectations of the Ontario Health and Physical Education curriculum for elementary school students. Therefore consent is not necessary for these activities because they are part of the regular curriculum. However, I give consent for Brock University to have access to the data collected from the fitness appraisals, questionnaires and movement appraisals. I understand that Brock University has received approved by the Research Committee of the District School Board of Niagara.

Child's Name:________________________________

School: ______________________________________

☐ I give consent for the Brock University research study, conducted by Dr. John Hay, to use my child's data collected from the fitness appraisal, questionnaire and movement appraisal.

☐ I DO NOT give consent for the Brock University research study, conducted by Dr. John Hay, to use my child's data collected from the fitness appraisal, questionnaire and movement appraisal.

Signature of Parent/Guardian: ________________________Date: ______________

Signature of Student: ________________________________Date: ______________

***PLEASE RETURN THIS FORM TO YOUR CHILD'S HOMEROOM TEACHER by November 11, 2004***

## Appendix VII

### PHAST – Phase II Informed Consent Form for School Assessments

**LETTER OF INFORMED CONSENT**
Physical Fitness Activity and Movement Research - Brock University

Principal Investigators: Dr. John Hay, Department of Community Health Sciences
Dr. John Cairney, University of Toronto
Dr. Brent Faught, Department of Community Health Sciences
Dr. Jian Liu, Department of Community Health Sciences

Dear Parents/Guardians:
The Brock University faculty members named above are continuing a study to investigate healthy growth and development and its association with the physical activity of children. For the past three years, your child has been part of the **PHAST** project and the Government of Canada has been so impressed with this work that they have provided funding for an additional three years. We are thankful for allowing your child to participate in **PHAST** and hope that you have found our reports of interest. We will now be able to provide you with an annual report of your child's growth and development status as well as their level of physical fitness for another three years. We will also be able to provide a complete nutritional analysis for each child. We will continue with the majority of the same measurements as before but will no longer be including bio-electric impedance measures of body composition in our assessments. We will be providing a single assessment report each year, in the fall, not two as in previous years.

As before, our funding allows us to support the District School Board of Niagara with resources and information to enhance their health and physical education programs. The assessments we conduct will compliment the Health and Physical Education curriculum in areas of diagnostic assessments for the purpose of personal fitness goals. Wherever possible we will provide complete assessments for every child. Our request of you is that you continue to allow us to take the assessment data from your child to use in our research of those factors that contribute to healthy growth and development. This data will continue to be completely confidential and individual reports will be shared only with yourself and your child's teacher. **The assessments will not be used as part of your child's school evaluation**. Only parents who have provided consent will receive the annual reports as we will not be able to keep or report the assessments of children without parental consent.

Below we have described each of the assessments that we will be making. We have noted which questionnaires or assessments are new to the study; the others have been completed by your child for the last three years. All assessments will be taken by trained University personnel during regular school class time.

**The Questionnaires**

Students will continue to complete three short questionnaires that allow them to report their enjoyment and confidence in being active as well as describing their physical activity habits and patterns. These questionnaires take about 20 minutes to complete. This year we are also able to provide for the first time a complete nutritional assessment (one year only) that takes about 20 minutes to complete. This assessment provides a computerized analysis of your child's nutrition – caloric intake, vitamins and minerals, etc. It asks only nutritional questions of the child and does not question medical status or family practices. These are very expensive questionnaires and so only children with consent will be able to complete them. Children without parental consent will be asked to work on other schoolwork during this portion of their health class.

**Fitness Appraisal**

As in the three previous years, all students will complete the 20 metre shuttle run. This common fitness assessment has students run 20 metre segments in time to a beat until they are unable to keep up to the timed beat. Children run in groups of 6-8 and are cheered on by their classmates. Children can stop running whenever they wish.

Physical fitness assessments include height, weight, and waist girth measurements that are taken using high quality medical scales. All these measures are taken privately in a screened area of the gymnasium where only the research assistant can see the results. All these assessments are made by female research assistants with children only asked to remove their shoes. We hope that that we may have sufficient funding to include a blood pressure measurement. This will be done by an automated blood pressure machine similar to those found in drug stores and hospitals. If we find any blood pressure readings that are outside the normal range we will report this to parents and suggest they discuss the results with their family doctor.

Any information we receive will be entered immediately into computer records using a code number with no name attached. All the information we collect will be kept absolutely confidential when being reported. In our reports we will only present the results of multiple schools, so that no single child, family, or school will be able to be identified. When the study is complete, a summary report on the findings will be available to interested parents at your school's main office.

There will be no effect on your child's school evaluation if their results are not entered in this project.  Your child's participation is voluntary and he/she may withdraw from the study at any time without any penalty. There is no obligation for your child to answer any or all questions or to participate in any aspect of this project.

All personal data will be kept strictly confidential and all information will be coded so that your child's name is not associated with his/her answers. Only the researchers named above will have access to the complete data. It is our intent to continue to publish the results of this research in scientific journals.  Again, no personal information regarding your child, school or school board will be identified or be possible within the publication.

This study has been reviewed and approved by the Brock University Research Ethics Board, (File #: 03-342) Research Services, Brock University, Room C315 - 905-688-5550 (Ext. 4315) and has been approved by the Research Committee of the District School Board of Niagara (June 7, 2007).

We greatly appreciate your co-operation. If you would like to receive more information about the study, review the questionnaires, or learn more about any of the appraisals, please contact **Dr. Brent Faught** at 905-688-5550, (Ext. 3586).

If you are willing to grant permission for your child to participate in this study, please complete the consent form below and have your child return it to their teacher immediately.

Thanks for your help!

John A. Hay, Ph.D., John Cairney, Ph.D.,

Brent E. Faught, Ph.D., Jian Liu, Ph.D.

**CONSENT FORM**

Child's Name: ______________________________________________________________

School: ________________________________________________________________

I give permission for my child to participate in the Brock University study (**PHAST**) conducted by Dr. John Hay, Dr. John Cairney, Dr. Jian Liu, and Dr. Brent Faught.

I do **NOT** give permission for my child to participate in the Brock University study conducted by Dr. John Hay, Dr. John Cairney, Dr. Jian Liu, and Dr. Brent Faught.

Signature of Parent/Guardian: ______________________________ Date: ____________

Signature of Student: __________________________________ Date: ____________

***PLEASE RETURN THIS FORM TO YOUR CHILD'S CLASS TEACHER!!***

**The PHAST project has also received funding that will allow us to provide a complete cardiovascular assessment of 400 children. This is an exceptional opportunity that includes a variety of advanced health assessments (no radiation). If you are willing to be contacted to discuss having your child be one of those selected to participate in this assessment please indicate below by providing your signature and phone number. This only provides permission for us to contact you to provide information about this opportunity!**

**Name: ____________________________________________________**

**Phone #: ______________________________**

**Best day/time for us to call you: Days: ______________________________**

**Times: ______________________________**