SMOKE EXPOSURE AND DEVELOPMENTAL COORDINATION DISORDER

INVESTIGATING THE ASSOCIATION BETWEEN EXPOSURE TO SECONDHAND SMOKE IN UTERO AND DEVELOPMENTAL COORDINATION DISORDER

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Abstract

Affecting approximately 5-6% of the primary school population, developmental coordination disorder (DCD) is a condition characterized by poor motor proficiency that interferes with a child's activities of daily living. The cause of DCD is not yet understood; however, it is known that children with DCD are more likely to have other co-occurring developmental disorders such as attention-deficit hyperactivity disorder (ADHD). While there is a growing body of evidence linking ADHD to smoke exposure in utero, there is limited research investigating a similar link between smoke exposure in utero and DCD. The purpose of this study was to examine the effect of SHS exposure in utero in children with DCD and a group of typically developing (TD) children.

Methods – A case-control study was conducted to compare children with DCD to TD children on their exposure to SHS in utero and other demographic variables. At baseline, participants included 63 DCD children and 63 healthy controls. All children were assessed for motor proficiency, intelligence, and ADHD. Mother's SHS exposure during pregnancy and other demographic variables were obtained from a parent completed survey.

Results – Multinomial logistic regression analyses revealed that children exposed to SHS in utero were significantly more likely to be at high risk for DCD than children who were not exposed to SHS in utero, even after adjusting for associated demographic variables.

Furthermore, children exposed to SHS in utero were significantly more likely to be at moderate-high risk for DCD, whether or not ADHD was co-occurring.

Conclusion – Results from this study suggest that exposure to SHS during pregnancy has negative effects on fetal development and appears to be a contributor for DCD. Further study is needed to examine the specific mechanisms linking SHS exposure in utero to motor coordination problems in children.

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List of Abbreviations

ADHD	Attention-Deficit Hyperactivity Disorder
BOTMP-SF	Bruininks Oseretsky Test of Motor Proficiency (Short Form)
CPRS-R:S	Conners' Parent Rating Scales-Revised: Short Form
DCD	Developmental Coordination Disorder
DAMP	Deficits in Attention, Motor Control, and Perception
DSM-5	Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition
KBIT-2	Kaufman Brief Intelligence Inventory – Second Edition
M-ABC-2	Movement Assessment Battery for Children – Second Edition
OT	Occupational Therapist
pDCD	probable DCD
PHAST	Physical Health Activity Study Team
SES	Socioeconomic Status
SHS	Secondhand Smoke
TD	Typically Developing

Chapter 1: Introduction

1.1.0 Preamble

Developmental Coordination Disorder (DCD) is a neuro-developmental disorder that is present from birth but does not become more apparent until a child begins formal schooling (Missiuna et al., 2008). A child is considered to have DCD when they lack the motor coordination necessary to carry out tasks that are appropriate for his or her intellectual ability. Not all children with DCD display the same motor difficulties, but the difficulties that are experienced tend to consistently affect new motor learning and the performance of complex motor tasks (Missiuna et al., 2008). In addition, children with DCD are known to participate less in team play and sports (Cairney, Hay, Faught, Mandigo, & Flouris, 2005b); struggle with emotional or behavioural problems (Missiuna et al., 2011); have impaired academic achievement (American Psychiatric Association, 2013); have poor self-esteem (Piek, Baynam & Barrett, 2006); and participate less in physical activity (Bouffard, Watkinson, Thompson, Causgrove-Dunn, & Romanow, 1996), putting them at greater risk for obesity (Cairney, Hay, Faught & Hawes, 2005a).

Currently, the origins of DCD are unclear; however, it is assumed that the cause is heterogeneous as there is currently no clear evidence as to whether DCD is a unitary disorder or whether subtypes of DCD exist (Dewey & Wilson, 2001). Through advances in structural and functional imaging of the brain, it is clear that wide areas of the brain are involved in the planning and performance of motor actions (Rowe & Frackowiak, 1999). As a result, most studies investigate the factors that influence this delicate network to identify the source of the difficulties experienced by children with DCD (Cermak &

Larkin, 2002). These factors most often include minor brain damage, genetic predisposition, or an impoverished environment (Cermak & Larkin, 2002).

Given the high co-occurrence of DCD with attention-deficit hyperactivity disorder (ADHD) (Pearsall-Jones, Piek, & Levy, 2010); it is of interest to study the factors currently shown to alter brain function for those with ADHD, within the DCD population. Of all the environmental factors implicated in causing ADHD that have been studied, maternal smoking during pregnancy has been found to be the most important risk factor identified to date (Landgren, Kjellman, & Gillberg, 1998; Zhou et al., 2014). Tobacco smoke, direct or indirect, contains thousands of life-threatening chemicals and many of these ingredients are potentially toxic to fetal development. Research has shown that nicotine, one of the main ingredients in tobacco, has long-term effects on brain function, cognition, and behavior (Beck et al., 2002; Dwyer, Broide, & Leslie, 2008). Studies focusing on some of the conditions that commonly occur with DCD have shown increased risk in children who were exposed to tobacco smoke in utero. For example, Schmitz et al. (2006) estimated an odds ratio of 3.44 for an increase in the inattentive form of ADHD for children whose mothers smoked $\geq$ 10 cigarettes per day during pregnancy.

Only one study to date has examined smoke exposure during pregnancy and the occurrence of motor control difficulties. Landgren et al., (1996) found a positive association between mothers who reported smoking during pregnancy and children displaying deficits in the three areas of: motor control, attention, and perception. While the findings were positive, the study did not directly identify DCD by using standardized

assessments. Children's motor control was rated by a physician using a 6-item test with the answer options of 'normal' or 'abnormal.' A child was deemed to have deficits in motor control if they received two or more abnormal scores out of the 6 items (Landgren, Pettersson, Kjellman, & Gillberg, 1996). Additionally, this study did not examine the effect of maternal smoke exposure during pregnancy on each area of interest independently.

Understanding the relationship between smoke exposure in utero and DCD will contribute to current literature supporting the notion that DCD is linked to negative environmental factors during pregnancy. Data is also limited on the effect of passive smoking by the mother on the developing fetus. A positive association between secondhand smoke (SHS) exposure in utero and DCD will further emphasize the importance of preventing smoking and smoke exposure during pregnancy. By further contributing to the knowledge of risks associated with smoking and smoke exposure during pregnancy, expectant mothers may be more likely to cease smoking and reduce exposure to SHS during pregnancy.

1.2.0 Objectives

The primary objective of this study was to examine the effect of SHS exposure in utero in children with DCD and a group of typically developing (TD) children. The secondary objective was to examine any change in effect when comparing children with DCD and ADHD, children with DCD without ADHD, and TD children.

1.3.0 Hypothesis

A positive association between SHS exposure in utero and the occurrence of DCD is anticipated. It is further expected that the association will be greater for those children with both DCD and ADHD.

Chapter 2: Literature Review

2.1.0 What is Developmental Coordination Disorder?

DCD is a neuro-developmental condition characterized by problems with both fine and gross motor coordination that result in impairment in everyday functioning, play, and academic achievement (Visser, 2003). Children with DCD struggle with self-care tasks (e.g., dressing, using utensils), school-related tasks (e.g., handwriting, organizing seatwork, physical education class), leisure activities (e.g., sports, playground activities), or with a combination of the above (Missiuna, Gaines, Soucie, & McLean, 2006a). Due to these challenges, children with DCD have historically been called 'clumsy' or 'physically awkward' (Missiuna et al., 2006). In 1994, a multidisciplinary group of researchers and clinicians from around the world gathered at an international consensus meeting and agreed to accept the term DCD to classify these children (Polatajko, Fox, & Missiuna, 1995). The diagnostic criteria that must be met for a diagnosis of DCD, according to the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5; American Psychiatric Association, 2013), requires that: (A) motor performance is substantially below expected levels, given the person's chronologic age and previous opportunities for skill acquisition; (B) motor performance disturbances significantly and persistently interfere with activities of daily living or academic achievement; (C) onset of symptoms is in the early developmental period; and (D) the motor skill deficits are not better explained by intellectual or visual impairment, and are not attributable to a neurological condition affecting movement. It should be noted that, for criterion D, most previous

studies of DCD in children have used IQ below 70 as an exclusionary criterion (Sugden, 2006).

The widely accepted prevalence rate of DCD is 5-6% of the primary school population, or approximately 1 in 20 children (American Psychiatric Association, 2013). Given average class room sizes in North America, this means that on average, DCD affects 1 to 2 children in every classroom (Missiuna, Rivard, & Pollock, 2004). It is not uncommon to find lower or higher prevalence rates, with the range of 1-22% in the primary school population (Cermak & Larkin, 2002; Missiuna et al., 2006). Given there is no gold standard to identify the condition, or clear definitions and diagnostic criteria for DCD, estimating the prevalence of DCD has proven to be difficult. Varying prevalence rates have been cited as a result of the definition used, tools chosen, or because of the percentile cut-off used to identify children with DCD. The large ALSPAC UK-based population study of 7 to 8 year-old children recently indicated that the inflated prevalence values often reported in literature are the result of unreliable measurement criteria (Lingam, Hunt, Golding, Jongmans, & Emond, 2009). Lingam's study showed a prevalence rate of 1.7% when they applied the requirements of the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition,* and only included those with severe motor coordination difficulties (Lingam et al., 2009). When using broader cut-off criteria on tests of motor coordination and activities of daily living, the researchers identified a further 3.2% of children as having 'probable DCD' (Lingam et al., 2009). This prevalence is similar to other studies that identified children in the same manner (van Dellen & Geuze, 1988; Wright & Sugden, 1996).

Studies of children with DCD also report a higher prevalence in boys than girls; however, the prevalence of movement difficulties in boys and girls has been a subject of conflicting data. For example, samples from referred clinical populations have shown a higher incidence of boys with DCD. Missiuna (1994) found a ratio of 5:1 males to females in teacher-referred children. This finding could be explained by the findings of Revie and Larkin (1993) who compared rates of identification of poor coordination by teachers of boys and girls. The girls whom the teachers identified as clumsy had significantly poorer motor coordination than the boys did (Revie & Larkin, 1993). This suggests that girls may have to present with more severe movement difficulties than boys in order to be diagnosed. In turn, teachers may have different expectations of skill levels in boys and girls, which may influence identification (Kirby, Sugden, & Purcell, 2014). Samples from population studies have reported a more equal distribution or a prevalence rate similar to that reported by the American Psychiatric Association, which reports a male to female prevalence ratio of 2:1 (Cairney et al., 2007; Lingam et al., 2009).

While DCD is sometimes referred to as a 'playground disorder' (Hay & Missiuna, 1998), its effect is felt far beyond monkey bars, slides, and swings. Research shows that the motor difficulties experienced by children with DCD are strongly associated with subsequent development of physical, academic, and mental health difficulties (Missiuna, Moll, King, Law, & King, 2006b). Of concern is the finding that children with DCD have repeatedly been shown to be less physically active than other children (Hay, Hawes, & Faught, 2004; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). As a result, children with DCD are at increased risk of becoming overweight or obese (Cairney et al., 2005a).

Furthermore, this may place them at increased risk for poor cardiovascular health (Cairney et al., 2005a) and, in the long term, early onset of chronic disease (Faught, Hay, Cairney, & Flouris, 2005). It was originally thought that children would outgrow their coordination impairment; however, it has been shown that motor problems persist into adolescence (Cantell & Kooistra, 2002; Cousins & Smyth, 2003), and the secondary effects of the disorder can impact a child well into adolescence and adulthood (Cantell, Smyth & Ahonen, 2003; Rasmussen, & Gillberg, 2000). This suggests the importance of early identification in order to potentially improve the quality of life for these children. Of greater importance is determining the cause of this disorder to potentially avoid or reduce its occurrence altogether.

2.2.0 Cause of Developmental Coordination Disorder

To achieve coordinated movement, a person requires the ability to process and interpret sensory information accurately. This allows them to select and execute the appropriate motor response, as well as, interpret information to make appropriate judgements (Cherng, Liang, Chen, & Chen, 2009). A consistent question of interest amongst researchers in the field of DCD is what causes disruptions in this process. While there are numerous theories about the cause of DCD, there is not enough evidence to offer a definitive answer about causality (Missiuna et al., 2006). Proposed theories have been investigated at different levels of analysis and with varying approaches to identify the source of the difficulties associated with DCD. Some factors that have been considered center around mild brain damage or dysfunction, genetic predisposition, information

processing deficits, or an impoverished environment (Cermak & Larkin, 2002; Cherng et al., 2009; Gillberg, 2003).

Skilled movement performance is dependent on accurate information processing of various stimuli (Cherng et al., 2009). Evidence exists that children with motor coordination difficulties also display difficulties with the speed and accuracy of processing information. The main findings of the study by Henderson, Rose, and Henderson (1992) found that children with DCD had a prolonged reaction time and prolonged movement time when asked to complete a simple aiming task, compared to children without DCD (Henderson, Rose, & Henderson, 1992). Additionally, Cherng, Liang, Chen, and Chen (2009) examined the effect of a concurrent motor task on walking in children with DCD, and found that walking was affected in children with DCD more so than in the comparison children. These findings suggest that these slower responses of children with DCD may be due to longer search for and retrieval of necessary information. Furthermore, they indicate a lack of automatization of motor actions in children with DCD when attentional demands increase (Cherng et al, 2009; Hadders-Algra, 2001).

Different areas of the brain are responsible for different responses depending on the task requirements. Dysfunction within a subsystem could have the ability to impair performance of specific tasks under certain circumstances, and also affect the fine tuning of movement (Sellers, 1995). As a result, several studies have examined various brain structures associated with DCD. The cerebellum has been recognized for its role in motor control and coordination, and more specifically, in smooth coordination of sequence,

force, and timing of muscle contractions involved in postural control and motor actions (Barlow, 2002). As a result, many behavioural studies have implicated the cerebellum as a possible site for motor dysfunction in children with DCD (Piek, 2004). Ivry, Keele, and Diener (1988) conducted a case study analysis of 7 patients with focal lesions in the cerebellum. It was found that patients with lateral lesions had deficits in central timing processes, and those with medial lesions had deficits in response rates (Ivry, Keele, & Diener, 1988). The researchers concluded that the lateral regions of the cerebellum are critical for the accurate functioning of the internal timing system, and as a result, these lesions impair fine motor coordination (Ivry et al., 1988). Another study by Piek, Dyck, Francis and Conwell (2007) assessed whether children with DCD had deficits on tasks measuring working memory, set-shifting, and processing speed. They found that children with DCD were significantly slower on all tasks, supporting past evidence of a timing deficits in these children possibly due to a disruption in cerebellar function (Lundy-Ekman, Ivry, Keele, & Woollacott, 1991). Evidence for a cerebellar role in DCD also comes from evidence of cerebellar involvement in commonly co-occurring disorders such as ADHD (Barkley & Murphy, 2006; Castellanos et al., 2002). While evidence surrounding the factors affecting brain development in children of DCD is limited, many studies have examined possible factors in children with ADHD.

2.3.0 Developmental Coordination Disorder Comorbid with Attention-Deficit Hyperactivity Disorder

DCD and ADHD frequently co-occur, with rates of comorbidity as high as 50% (Kadesjö & Gillberg, 1999; Kaplan, Wilson, Dewey, & Crawford, 1998; McLeod, Langevin, Goodyear, & Dewey, 2014; Pearsall-Jones et al., 2010; Piek, 2004). This overlap of motor and attention problems has long been recognized (Zwicker, Missiuna, & Boyd, 2009). ADHD is characterized by symptoms of inattention and/or hyperactivity across multiple settings, which results in performance issues in social, educational, or work settings (American Psychiatric Association, 2013). ADHD is the most commonly diagnosed childhood psychiatric disorder, with an estimated prevalence rate of 3-10% among school-aged children (Rowland, Lesesne, & Abramowitz, 2002; Scahill & Schwab-Stone, 2000). Children with this disorder are at a greater risk for longer term negative outcomes, such as lower education and employment attainment (Harpin, 2005). While previously thought that children eventually outgrow ADHD, recent studies suggest that up to 60% of affected individuals continue to show significant symptoms of the disorder into adulthood (Weiss & Hechtman, 1993).

As with DCD, the exact causes of ADHD are unknown. Despite the high rate of heritability for ADHD, some evidence points to disrupted brain structures, and more specifically, abnormalities in the cerebellum (Zwicker et al., 2009). A study by Castellanos et al. (2002) compared regional brain volumes of children with ADHD and healthy controls. The study involved 152 children and adolescents with ADHD aged 5-18 years and 139 age- and sex-matched controls. Children with ADHD had significantly smaller cerebellar volumes compared to controls. Diffusion tensor imaging technology, which measures the integrity of white matter tracts using fractional anisotropy, has

provided further evidence of cerebellar involvement in ADHD (Zwicker et al., 2009). Ashtari et al. (2005) explored white matter abnormalities in 18 children with ADHD and 15 age- and gender-matched healthy controls. Children with ADHD had decreased fractional anisotropy in the left middle cerebellar peduncle and left cerebellum.

Along with evidence supporting disrupted brain structures for those with ADHD, it is also clear that numerous environmental factors influence these structures beyond genetic risk. Of all the environmental factors implicated in causing ADHD that have been studied, maternal smoking during pregnancy has been found to be the most important risk factor identified to date in animal experiments (DiFranza, Aligne, & Weitzman, 2004; Giedd, Blumenthal, Molloy, & Castellanos, 2001; Linnet et al., 2003) and human studies (Kotimaa et al., 2003; Langley, Holmans, Van de Bree, & Thapar, 2007; Weissman, Warner, Wickramaratne, & Kandel, 1999; Zhou et al., 2014). Maternal smoking during pregnancy has been consistently associated with a two- to four-fold increased risk for ADHD in both case-control and cohort studies (Altink et al., 2009; Langley, Rice, van den Bree, & Thapar, 2005; Linnet et al., 2003). One human study of particular interest, conducted by Thapar et al. (2003), examined whether smoking during pregnancy is associated with symptoms of ADHD in offspring and whether these effects are in addition to genetic influences, since mothers and their children share, on average, half of their genes in common. ADHD and smoking initiation are both highly heritable (Thapar et al., 2003); one cannot rule out the possibility that the observed association between smoking during pregnancy and ADHD in offspring is explained by a common set of genes influencing both the risk factor and outcome. A twin study design was used to establish

the contribution of genetic influences on ADHD. In total, data were obtained for 2,054 twin pairs using both maternal and teacher reports. It was found that maternal smoking during pregnancy showed a significant association with ADHD symptoms in offspring, over and above, the influence of additive genetic factors and non-shared environmental influences (Thapar et al., 2003). Of additional importance is the study conducted by de Zeeuw et al. (2012) who explored the effect of prenatal exposure to cigarettes and alcohol on brain volume in children with ADHD and TD controls. For prenatal exposure to cigarettes, a graded pattern was found. Children with ADHD who had been exposed had the smallest cerebellum volumes, followed by unexposed subjects with ADHD, and unexposed controls showing the largest volumes.

Similar research with DCD is extremely limited. Previous studies have investigated smoking in pregnancy and physical control and coordination in offspring, but not specifically DCD. In a study of 362 children, smoking in pregnancy was associated with a small adverse effect on balance at age 5 years (Trasti, Vik, Jacobsen, & Bakketeig, 1999). In another study involving 593 children aged 10 years, maternal smoking during pregnancy was associated with a modest decrease in coordination on the non-dominant side of the body (Cornelius, Ryan, Day, Goldschmidt, & Jennifer, 2001). This was confirmed by another study examining data from 13,207 members of the National Child Developmental Study, in which tests of physical control and coordination were administered by a school doctor at the age of 11 years (Larsson & Montgomery, 2010).

One study of importance was conducted by Landgren, Kjellman, and Gillberg (1998) which examined the contribution of certain social, familial, prenatal, perinatal, and developmental background factors in the pathogenesis of deficits in attention, motor control, and perception (DAMP). This population based case-control study involved 113 children aged 6 years, 62 diagnosed with DAMP and 51 controls without DAMP. Smoking in pregnancy was recorded as present if the mother reported smoking more than the occasional cigarette during pregnancy. The study found that smoking during pregnancy had occurred more often in children with DAMP (36% vs. 16% in the comparison group). In univariate analysis, smoking during pregnancy was significantly associated with the occurrence of DAMP, as well as a higher frequency of ADHD symptoms. Further analyses indicated an independent effect of maternal smoking during pregnancy on the development of DAMP (Landgren, Kjellman, & Gillberg, 1998).

2.4.0 Effects of Smoke Exposure during Pregnancy

Environmental factors can significantly alter brain development during gestation, and one harmful factor is maternal smoke exposure, directly and indirectly. Globally, 22% of the world's adult population aged 15 years and over are estimated to be current tobacco smokers, including 36% of men and 8% of women (World Health Organization, 2011). In addition, more than one third of women aged 15 years and above are estimated to be regularly exposed to SHS (Öberg, Woodward, Jaakkola, Peruga, & Prüss-Ustün, 2010). Although some women cease smoking when they become pregnant, many

continue to use tobacco throughout pregnancy or permit smoking in their homes (World Health Organization, 2013).

In utero smoke exposure differs from inhalation exposure, whether passive or active, in that toxic substances dissolved in the blood of the mother reach the body of the fetus through placental circulation instead of the lungs. SHS is composed of more than 4000 chemicals and more than 250 of these are known to be carcinogenic or toxic in some other way (Zhou et al., 2014). Many of these substances are known to cross the placenta and reach the fetus at levels higher than maternal levels, regardless if the mother is an active or passive smoker (Lee et al., 2011; Tiesler & Heinrich, 2014). Furthermore, although SHS exposure is a diluted form of exposure, certain toxic chemicals such as ammonia, nitrogen oxides, and the volatile N-nitrosamines, are present at higher proportions in SHS than in mainstream smoke (IARC, 2002; National Research Council, 1986). Almost every developing organ system, including the lungs, brain, heart, and ears, appears to be affected by prenatal exposure to tobacco (Zhou et al., 2014). Nicotine is one of the major components in tobacco smoke. It is most often concentrated in the fetal tissue at levels as much as 15% higher than maternal levels (Huizink & Mulder, 2006) and has been shown to have adverse effects on fetal growth (Nomura, Marks, & Halperin, 2010) and neural development (Dempsey & Benowitz, 2001). These adverse effects have long-term implications on brain function, cognition, and behaviour (Beck et al., 2002; Dwyer, Broide, & Leslie, 2008). Kandel, Wu, and Davies (1994) collected data showing that nicotine input during critical periods of development can alter gene expression and can produce long-lasting functional and structural changes in the brain.

Although evidence is limited, several studies have investigated the relationship between SHS exposure in utero and cognitive outcomes. In a prospective study that assessed prenatal SHS exposure on the neurodevelopment of infants aged 6 months, deficits in development were found in those who were exposed to tobacco smoke in utero compared with those who were not exposed (Lee et al., 2011). A study by Hernández-Martínez, Val, Subías, and Sans (2012) examined the effects of smoke exposure during pregnancy on neonatal behaviour, including mothers exposed to SHS. The results showed that both active and passive smoking during pregnancy affects several aspects of neurobehavioral development, regardless of socio-demographic, obstetric and pediatric factors.

2.5.0 Summary

Tobacco exposure during pregnancy, active or passive, has been linked to a range of neuro-developmental outcomes in children, including ADHD. DCD and ADHD are highly comorbid and therefore, it is reasonable to assume that SHS exposure in utero may also be a risk factor for DCD. The study conducted by Landgren, Kjellman, and Gillberg (1998) found this to be true for those children with DAMP. The study found an independent effect of maternal smoking during pregnancy on the development of DAMP, which includes deficits in attention and motor control. At the same time, because of comorbidity, a link between SHS exposure in utero and DCD may be falsified in that SHS exposure in utero is causing attentional problems, but not motor problems. Although DCD is commonly linked with ADHD, it is not often addressed or diagnosed in studies of

children with ADHD. Therefore, these studies are likely to include children with both DCD and ADHD. This means that any association with SHS exposure in utero may be in children with DCD; however, if DCD is not measured, then it remains unknown. The present study addressed this gap by measuring both DCD and ADHD to see if an association between SHS exposure in utero and the occurrence of DCD only and DCD comorbid with ADHD exists.

Chapter 3: Research Questions

3.1.0 Research Questions

3.1.1 Is there an association between being exposed to SHS in utero and the occurrence of DCD?

3.1.2 Does the association between being exposed to SHS in utero and the occurrence of DCD change when examining the occurrence of children who have DCD only and those who have DCD comorbid with ADHD?

3.2.0 Research Objective

The primary objective of this study was to examine the influence of SHS exposure in utero on the occurrence of DCD in children. This was done by conducting secondary data analysis of a cross-sectional study involving a group of children drawn from a large, prospective cohort study. Statistical modelling was used to compare children with DCD to children without DCD on the factor of SHS exposure in utero.

3.3.0 Testing the Research Questions

Level of motor impairment for each child was determined by performance on the Movement Assessment Battery for Children – Second Edition (M-ABC-2; Henderson, Sugden, & Barnett, 2007). The European Academy of Childhood Disability recently published guidelines suggesting the use of $\leq 15^{th}$ percentile on the M-ABC-2 as a definition of DCD (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012). Previous guidelines recommended a score of $\leq 5^{th}$ percentile to classify children with DCD

(Sugden, 2006). Given this, the study sample was divided into children with scores ≤5th percentile (high risk DCD) and scores between the 6th and 15th percentile (moderate risk DCD). Children with scores ≥16th percentile were classified as non-DCD. Baseline characteristics were first computed for the entire sample. Group differences were then evaluated using ANOVA with Bonferroni post-hoc contrasts and chi-square analysis for all demographic variables and SHS exposure. Multinomial logistic regression was performed to examine the effect of SHS exposure in utero on the occurrence of DCD adjusting for age, sex, birth weight, premature birth, and household income. Lastly, the two DCD groups were collapsed to form one DCD group of children with scores ≤15th percentile (moderate-high risk DCD). Children were then regrouped based on their M-ABC-2 scores and ADHD index t-scores: (1) moderate-high risk DCD with ADHD (≥66 t-score), (2) moderate-high risk DCD without ADHD (<66 t-score), and (3) non-DCD. Group differences were evaluated as before and multinomial logistic regression was performed again to determine the effect of SHS exposure in utero on the occurrence of moderate-high risk DCD only and moderate-high risk DCD with ADHD, adjusting for age, sex, birth weight, premature birth, and household income.

Chapter 4: Methods

4.1.0 Research Design

This study involved a cross-sectional investigation of a subset of participants drawn from the large, prospective cohort study called the Physical Health Activity Study Team (PHAST) project. The PHAST study examined the effect of poor motor proficiency on the activity levels of children and the resultant effects on their health – physical, social, psychological, and academic. The PHAST study was conducted in two phases.

PHAST I (phase I) began in September 2004 with semi-annual school-based physical assessments of all consenting children enrolled in grade 4 at one of the 75 participating elementary schools (of a possible 90) in the Niagara region of Ontario. Motor skills were assessed using the short form of the Bruininks Oseretsky Test of Motor Proficiency (BOTMP-SF). Given the expense of testing all children at the same time-point in the study, and knowing that DCD does not generally improve with time (Hellgren, Gillberg, Gillberg & Enerskog, 1993), motor coordination was assessed across three different data-collection points with each child assessed only once. All 75 participating schools were randomly divided into three groups; children in the first group of schools were screened in fall of 2005, children in the second group of schools were tested in spring of 2006, and lastly, children in the third group of schools were assessed in spring of 2007. In addition, a re-assessment of a random sample of 24 children by a pediatric Occupational Therapist (OT) was conducted, and results supported the validity of the testing approach. To further test the assumption that children's motor skills remain stable, 77 children drawn from a randomly selected subset of schools were re-tested using

the BOTMP-SF. Different examiners, blind to the original results, performed these reassessments. The correlation between the two sets of scores was 0.70 ($p < 0.001$) and this was judged to be acceptable. Differences reflected limitations of the instrument's test-retest and inter-rater reliability, as well as, any changes in presentation.

PHAST I, ending in June 2007, set the stage for PHAST II (phase II), which began in September 2007. Of the 2,519 participating students in phase I, 1,785 students from 62 participating elementary and secondary schools agreed to participate in phase II. Phase II involved annual school-based physical assessments (as before), and also introduced a lab-based component to further investigate cardiovascular risk factors in children with probable DCD (pDCD). The term probable was used since assessments in phase I were administered on location by trained research assistants and not as a diagnostic protocol administered by a professional. Additionally, criterion B of the four diagnostic criteria required for diagnosis was not measured.

PHAST I and II were reviewed and approved by the Research Ethics Board of Brock University and the District School Board of Niagara (Appendix A; Appendix B). Those participating in the lab-based component of phase II, which utilized a case-control design, comprised the study population for this investigation.

4.2.0 Study Population

In the fall of 2007, at the start of PHAST II, consent forms were sent home to all students who participated in PHAST I. This was to obtain consent for PHAST II, and also to receive permission to contact students to participate in the lab-based component of the

study being conducted at Brock University. A total of 1,785 completed consent forms were returned, and of those, 963 participants agreed to be contacted for the laboratory assessments.

To maximize the number of consent forms returned by those identified as having pDCD in PHAST I, a list was formulated of all the pDCD students that scored below the 5th percentile on the BOTMP-SF (n=118; 74 F, 44 M). All of these students were called 48 hours after the consent forms were sent home to ensure that the consent form was seen and completed, and also to answer any questions. Parents of children attending a non-participating school were also contacted and given information about the lab assessments. Of the 118 students initially contacted, a total of 47 accepted, with others declining because they were not interested (n=58), had moved out of the region (n=2), were unable to make contact (n=9), or the study didn't have contact information (n=2). To increase the sample size, the pDCD list was extended to include those students who scored at the 6th percentile, up to and including, the 10th percentile on the BOTMP-SF (n=80; 48 F, 32 M). From this group, 20 accepted, with others declining because they were not interested (n=40), the children were not integrated into the classroom (n=3), or the study didn't have contact information (n=17). These efforts resulted in a total of 67 children who were classified as pDCD. These children were then matched to controls of the same sex, school region[1], and age within 6 months.

After assessing motor impairment using the M-ABC-2 within the lab setting, 14 of the cases who were pDCD tested as controls (≥16th percentile), and 11 of the apparent

[1] A few cases were not able to be matched to children from the same school. In these situations, controls from a school within the same school region and closest proximity, were selected.

controls showed enough motor impairment to qualify as a case of pDCD ($\leq 15^{th}$ percentile). An additional case was excluded because of a neurological condition. Therefore, the final sample at the end of the first year of lab testing included 63 case-control pairs.

4.3.0 Experimental Protocol

Pre-assessment telephone invitations were conducted for those selected to participate in the lab-based study. During this time, verbal consent was obtained and participants were scheduled for an appointment in the Applied Health Sciences Laboratory at Brock University. Upon arrival, participants and parents reviewed and signed the study consent letter. (Appendix C). Both the child and parent were also asked to complete a series of questionnaires to obtain detailed information on medical conditions and/or medications, handedness, pubertal stage, medical and academic history, behaviour, and hypermobility. Following this, the participant was led through a series of assessments as summarized in Figure 4.1. Trained research assistants assessed the children on the components of body composition, cardiovascular health, and physical fitness. A registered pediatric OT administered the Kaufman Brief Intelligence Inventory, 2^{nd} edition (KBIT-2) and M-ABC-2. The research assistants and OT were naive to the pDCD status of the child. To ensure completeness of all the assessments, a research assistant led the child through the lab protocol and checked that all the information was obtained on the Advanced Health Assessment Information Sheet (Appendix D). The

entire lab component took approximately 2 hours to complete. Measurements relevant to this study are described in more detail in the following sections.

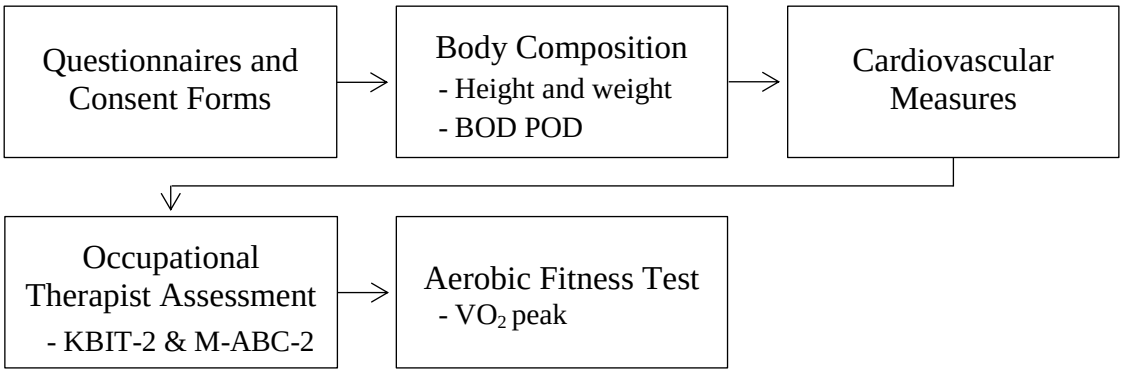

Figure 4.1. Procedure for PHAST lab testing

4.4.0 Experimental Measures

4.4.1 Motor Coordination

Motor coordination was assessed by a certified pediatric OT using the M-ABC-2 (Henderson, Sugden, & Barnett, 2007), a revision of the Movement Assessment Battery for Children (Henderson & Sugden, 1992). The M-ABC-2 is a standardized test that is used to identify motor impairment in children aged 3-16 years (Henderson, Sugden, & Barnett, 2007). The M-ABC-2 is divided into three age bands (3-6 years, 7-10 years, and 11-16 years) and the third age band (11-16 years) was used for this study. Within each age band, 8 motor tasks are evaluated which are grouped under three headings: Manual Dexterity; Aiming & Catching; and Balance (static and dynamic). A standard score is given for each motor task and these individual scores are summed to give an overall impairment score (age adjusted) and associated percentiles (Henderson, Sugden, &

Barnett, 2007). Scores between the 6th and 15th percentile are indicative of borderline movement impairment, while scores at or below the 5th percentile are indicative of a definite motor problem (Henderson, Sugden, & Barnett, 2007). Test re-test reliability and standard error of measurement for the total test scores have been reported to be 0.80 and 1.34, respectively (Henderson, Sugden, & Barnett, 2007).

4.4.2 Cognitive Ability

Cognitive ability (verbal and non-verbal) was also assessed by a certified pediatric OT using the KBIT-2, which is a well-recognized standardized measure of estimated intelligence that has been used in large studies to estimate children's cognitive ability. This quick and reliable measure requires no reading or writing, and is suitable for children 4 years of age and older (Kaufman & Kaufman, 2004). The KBIT-2 measures two distinct cognitive functions (verbal and non-verbal) through three subtests (verbal knowledge, matrices, and riddles). The KBIT-2 composite score has been shown to correlate well ($r = 0.77$) (Seagle & Rust, 1996) with the full composite of the Weschler Intelligence Scale for Children-IV (WISC-IV) (Wechsler, 2003). Children with an estimated intelligence quotient less than 70 are considered to be below average intelligence. With these children, motor abilities may not be distinguishable from their cognitive impairments.

4.4.3 Attentional Difficulties

The Conners' Parent Rating Scales-Revised: Short Form (CPRS-R:S) was selected to assess for ADHD. The short form, suitable for children 3-17 years of age, was selected in order to minimize respondent burden as it only consists of 27 items (compared to 93 items in the long form) and has a completion time of 5-10 minutes (Conners, 1997). For this scale, parents are asked to rate how much each of the 27 symptoms have been a problem for their child during the last month using a 4-point scale ranging from 0 (Not True at All) to 3 (Very Much True). Each item falls into one of four subscales: Oppositional (6 items), Hyperactivity (6 items), Cognitive Problems (6 items), and an ADHD Index (12 items). Sub-scores are summed and the raw score is transformed into a T-score which is then easily converted to a percentile rank. A T-score higher than 65 for the ADHD Index provides strong evidence of an attentional problem (Conners, 1997). The CPRS-R:S has demonstrated high sensitivity (92%), specificity (94.5%), and overall accuracy (93.4%) in males and females aged 3-17 years (Conners, Sitarenios, Parker, & Epstein, 1998).

4.4.4 Medical History and Household Demographic Survey

A parent or guardian of the child (mother preferred) was asked to complete the Medical Academic History Questionnaire put together by the PHAST II study team. Questions asked were those that the team deemed important to collect regarding the medical and academic history of the child and their family. Questions of importance to this study included SHS exposure during pregnancy, birth weight, premature birth, and household income.

To determine SHS exposure, parents were asked to indicate if the mother was exposed to "second hand smoke" on a regular basis during pregnancy. The answer provided was either yes or no. This is the only question that addressed primary or secondary smoke exposure during pregnancy. For birth weight, parents were asked to indicate their child's weight at birth. Low birth weight has been shown to be a risk factor for motor coordination problems (Goyen & Lui, 2009). Parents were also asked if their child's birth was considered premature with the option of answering yes or no. Lastly, for household income, parents were asked to indicate which range the total income of the household was in, ranging from $0 to greater than $150,000 per year. This measure was included to assess family socioeconomic status (SES). Although SES is not considered a risk factor for DCD, SES is a risk factor for low birth weight and premature delivery (Parker, Schoendorf, & Kiely, 1994).

4.5.0 Statistical Analysis

Statistical analyses were performed using SPSS version 22 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp) and the level of significance was set to $p \leq 0.05$. Baseline characteristics were first computed for the entire sample. ANOVA with Bonferroni post-hoc contrasts and chi-square analyses were then used to compare the three DCD groups of children (high risk DCD, moderate risk DCD and non-DCD) regarding age, sex, birth weight, premature birth, household income, and SHS exposure. Multinomial logistic regression, which allows for more than two categories of the outcome variable, was performed to examine the effect of SHS

exposure in utero on the DCD groups. An adjustment was made for the aforementioned demographic variables as these variables have all been shown to be associated with DCD. To determine that the effect of one characteristic is not supressed by another, all the demographic variables were adjusted for at the same time. Children within the high and moderate risk DCD groups were then grouped together (moderate-high risk DCD) and placed into one of three groups based on ADHD ratings (moderate-high risk DCD with ADHD, moderate-high risk DCD without ADHD, and non-DCD). Group differences were evaluated as before using ANOVA with Bonferroni post-hoc contrasts and chi-square analyses. Multinomial logistic regression was performed again to determine the effect of SHS exposure in utero on the occurrence of moderate-high risk DCD only, and moderate-high risk DCD with ADHD, adjusting for age, sex, birth weight, premature birth, and household income.

Chapter 5: Results

5.1.0 Participant Characteristics of Entire Sample

As previously mentioned, the original sample consisted of 126 students involved in the laboratory-based prospective case-control study examining the cardiovascular health of children with pDCD. Four children in this sample scored below 70 on the KBIT-2. According to the Leed's consensus, children with an IQ below 70 may have motor coordination difficulties that are consistent with their cognitive ability (Sugden, 2006). Therefore, these children were removed from the sample, and as a result, complete data was available for 122 subjects. It should be noted that the European Academy for Childhood Disability guidelines state that, given the complexities of arbitrating between cut-offs and determining discrepancy scores of cognitive ability, a categorical decision (above or below a specific IQ level) may not be as helpful to distinguish between children with DCD and children with coordination problems due to mental retardation, as previously thought (Blank et al., 2012). It is now recommended that motor dysfunction should be defined as DCD if the other criteria for diagnosis are fulfilled and if clinical history and examination cannot explain the motor problems and their impact on daily activities by cognitive status (Blank et al., 2012). Given that not all criteria for diagnosis, as outlined in the DSM-5, were met for this study, and that clinical history and examination were not available, the removal of these children from the sample was justified.

Baseline demographic characteristics are shown in Table 5.1 for 122 subjects. The mean age at the time of testing was 12.9 (±0.51), and there were more males (n=72) than

females (n=50). Subjects were classified into one of three groups based on their M-ABC-2 scores: (1) high risk DCD (≤5th percentile; n=45), (2) moderate risk DCD (between the 6th and 15th percentile; n=14), and (3) non-DCD (≥16th percentile; n=63). For the entire sample, 38.5% of the children had a mother indicate exposure to SHS while pregnant.

Table 5.1. Baseline characteristics of participants from the entire sample

Demographic Variable	All Participants n=122
Age (years)	
Mean (SD)	12.9 (0.51)
(min-max)	(12-14)
Sex % (n)	
Male	59.0% (72)
Female	41.0% (50)
DCD Classification % (n)	
High risk DCD (≤5th percentile)	36.9% (45)
Moderate risk DCD (6th-15th percentile)	11.5% (14)
Non-DCD (≥16th percentile)	51.6% (63)
SHS Exposure % (n)	
Yes	38.5% (47)
No	59.0% (72)
Missing	3

5.2.0 Participant Characteristics by Motor Proficiency

Baseline demographic characteristics by DCD groups (high risk DCD, moderate risk DCD, non-DCD) are summarized in Table 5.2. This table shows the test for group differences (ANOVA with Bonferroni post-hoc contrasts) for age and birth weight. It also shows the results of chi-square analyses to assess differences between groups in relation to sex, premature birth, and household income. There were no significant differences between groups in terms of age, sex, birth weight, premature birth, and household income.

Table 5.2. Baseline characteristics of participants with DCD (high and moderate risk) and without DCD

Demographic Variable	High risk DCD (≤5th %ile) n = 45	Moderate risk DCD (6th-15th %ile) n = 14	Non-DCD (≥16th %ile) n = 63	Testing Differences
Age (years)				
Mean (SD)	13.00 (0.60)	12.93 (0.48)	12.86 (0.44)	F(2,119)=1.044
(min-max)	(12-14)	(12-14)	(12-14)	p=0.355
Sex % (n)				
Male	64.4% (29)	42.9% (6)	58.7% (37)	X^2=2.062, df=1
Female	35.6% (16)	57.1% (8)	41.3% (26)	p=0.357
Birth Weight (kg)				
Mean (SD)	3.48 (0.60)	3.21 (0.66)	3.46 (0.50)	F(2,108)=1.298
(min-max)	(1.98-4.68)	(1.87-4.08)	(2.47-4.71)	p=0.277
Missing	8	0	3	
Premature Birth % (n)				
Yes	8.9% (4)	14.3% (2)	6.3% (4)	X^2=1.027, df=2
No	86.7% (39)	85.7% (12)	93.7% (59)	p=0.598[1]
Missing	2	0	0	
Household Income % (n)				
$0-29,999	20.0% (9)	21.4% (3)	15.9% (10)	X^2=8.023, df=10
$30,000-59,999	35.6% (16)	42.9% (6)	23.8% (15)	p=0.627[2]
$60,000-89,999	20.0% (9)	21.4% (3)	19.0% (12)	
$90,000-119,999	8.9% (4)	7.1% (1)	20.6% (13)	
$120,000-149,999	2.2% (1)	7.1% (1)	6.3% (4)	
$150,000 and over	8.9% (4)	0.0% (0)	11.1% (7)	
Missing	2	0	2	

[1]2 cells had expected count less than 5
[2]9 cells had expected count less than 5

5.3.0 Descriptive Analysis for Secondhand Smoke Exposure by Motor Proficiency

Table 5.3 shows SHS exposure in utero by DCD groups (high risk DCD, moderate risk DCD, non-DCD). A higher percentage of mothers with children classified as high risk DCD reported being exposed to SHS while pregnant (53.3%), compared to those with children classified as moderate risk DCD (35.7%), or as non-DCD (28.6%). These differences in SHS exposure were compared between the groups using chi-square analysis. The results revealed significant differences for SHS exposure (p=0.013)

indicating that mothers of children in both the high and moderate risk DCD groups were significantly more likely to have been exposed to SHS while pregnant.

5.3. Differences in SHS exposure between children with DCD (high and moderate risk) and without DCD

	High risk DCD (≤5th %ile) n = 45	Moderate risk DCD (6th-15th %ile) n = 14	Non-DCD (≥16th %ile) n = 63	Testing Differences
SHS Exposure % (n)				
Yes	53.3% (24)	35.7% (5)	28.6% (18)	**X^2=8.703, df=2**
No	40.0% (18)	64.3% (9)	71.4% (45)	**p=0.013**
Missing	3	0	0	

5.4.0 Multinomial Logistic Regression with Motor Proficiency

Multinomial logistic regression was used to explore the primary objective of this study. In model 1, the odds ratio was first calculated for SHS exposure and DCD (high and moderate risk) to provide an unadjusted measure of association for the effect of SHS exposure in utero on DCD (see Table 5.4). A significant association was not found with the moderate risk DCD group. For those in the high risk DCD group, SHS exposure in utero was found to be a significant predictor of DCD (p=0.004). The odds of a child developing high risk DCD when exposed to SHS in utero were 3.33 times greater than the odds for a child not exposed to SHS in utero. An odds ratio was then calculated for SHS exposure and DCD (high and moderate risk) adjusting for age, sex, birth weight, premature birth, and household income, as seen in model 2. Even though no differences in demographic variables were found between groups, these variables were still adjusted for because bivariate differences (see Table 5.2) are not the same as statistical adjustment

in a multivariate model. Specifically, the effect of one characteristic (e.g., sex) could be supressed by another effect, and this is only evident when adjusting for both effects at the same time. As seen in model 2 (see Table 5.4), after adjustment, the effect of SHS on DCD increased slightly (p=0.012) for the high risk DCD group. This increase shows that the effect of DCD was supressed in model 1 without the adjustment of the other factors. A significant association was not found in model 2 for the moderate risk DCD group.

5.4. The association between SHS exposure in utero and DCD (high and moderate risk) by multinomial logistic regression analysis

	High risk DCD (≤5th percentile)				Moderate risk DCD (6th-15th percentile)			
	Model 1		Model 2		Model 1		Model 2	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
SHS Exposure	**3.33 (1.47-7.57)**	**0.004**	**3.37 (1.30-8.75)**	**0.012**	1.39 (0.41-4.72)	0.598	0.73 (0.17-3.08)	0.671
Age			1.67 (0.64-4.39)	0.299			1.04 (0.29-3.76)	0.958
Sex			0.89 (0.35-2.23)	0.802			1.57 (0.44-5.59)	0.485
Birth Weight			1.52 (0.63-3.66)	0.351			0.56 (0.17-1.89)	0.352
Premature Birth			1.34 (0.19-9.54)	0.772			2.38 (0.27-21.32)	0.438
Household Income			0.89 (0.66-1.21)	0.450			0.65 (0.38-1.11)	0.113

5.5.0 Participant Characteristics by Motor Proficiency and Attention-Deficit Hyperactivity Disorder

To address the second objective of this study, the effect of SHS on comorbid DCD and ADHD was examined. Given sample size, the two DCD groups (high and moderate risk) were collapsed together to form the moderate-high risk DCD group ($\leq 15^{th}$ percentile). ADHD was then introduced and the following three groups were created: (1) moderate-high risk DCD with ADHD ($\geq$66 t-score), (2) moderate-high risk DCD without ADHD (<66 t-score), and (3) non-DCD. One participant was excluded from analysis because they did not have the CPRS-R:S completed. Next, these newly created groups were examined for differences on the same characteristics previously examined (see Table 5.5). The test for group differences (ANOVA with Bonferroni post-hoc contrasts) for age and birth weight are shown. Chi-square analyses were completed to assess differences between groups in relation to sex, premature birth, and household income. There were no significant differences between groups in terms of age, sex, birth weight, premature birth, and household income.

5.5. Baseline characteristics of participants with moderate-high risk DCD (with and without ADHD) and without DCD

Demographic Variable	Moderate-high risk DCD (≤15th %ile) **w/** ADHD n = 19	Moderate-high risk DCD (≤15th %ile) **w/o** ADHD n = 39	Non-DCD (≥16th %ile) n = 63	Testing Differences
Age (years)				
Mean (SD)	13.05 (0.62)	12.95 (0.56)	12.86 (0.44)	F(2,118)=1.186
(min-max)	(12-14)	(12-14)	(12-14)	p=0.309
Sex % (n)				
Male	52.6% (10)	61.5% (24)	58.7% (37)	X^2=0.194, df=1
Female	47.4% (9)	38.5% (15)	41.3% (26)	p=0.659
Birth Weight (kg)				
Mean (SD)	3.24 (0.73)	3.48 (0.57)	3.46 (0.50)	F(2,108)=1.047
(min-max)	(1.87-4.68)	(1.98-4.54)	(2.47-4.71)	p=0.354
Missing	4	3	3	
Premature Birth % (n)				
Yes	10.5% (2)	10.3% (4)	6.3% (4)	X^2=0.695, df=2
No	84.2% (16)	89.7% (35)	93.7% (59)	p=0.706[1]
Missing	1	0	0	
Household Income % (n)				
$0-29,999	26.3% (5)	17.9% (7)	15.9% (10)	X^2=7.838, df=10
$30,000-59,999	42.1% (8)	35.9% (14)	23.8% (15)	p=0.645[2]
$60,000-89,999	15.8% (3)	23.1% (9)	19.0% (12)	
$90,000-119,999	5.3% (1)	10.3% (4)	20.6% (13)	
$120,000-149,999	5.3% (1)	2.6% (1)	6.3% (4)	
$150,000 and over	5.3% (1)	7.7% (3)	11.1% (7)	
Missing	0	1	2	

[1] 2 cells had expected count less than 5
[2] 8 cells had expected count less than 5

5.6.0 Descriptive Analysis for Secondhand Smoke Exposure by Motor Proficiency and Attention-Deficit Hyperactivity Disorder

Table 5.6 shows SHS exposure in utero by DCD-ADHD groups (moderate-high risk DCD with ADHD, moderate-high risk DCD without ADHD, non-DCD). More mothers of the children classified as moderate-high risk DCD with ADHD reported being exposed to SHS while pregnant (52.6%), than those in the moderate-high risk DCD

without ADHD group (48.7%), or non-DCD group (28.6%). Chi-square analysis was used to test these differences and the results revealed significant differences for SHS exposure (p=0.027). Therefore, mothers of children with moderate-high risk DCD, whether on its own or in combination with ADHD, were significantly more likely to have been exposed to SHS while pregnant.

5.6. Differences in SHS exposure between children with moderate-high risk DCD (with and without ADHD) and without DCD

Demographic Variable	Moderate-high risk DCD (≤15th %ile) **w/** ADHD n = 19	Moderate-high risk DCD (≤15th %ile) **w/o** ADHD n = 39	Non-DCD (≥16th %ile) n = 63	Testing Differences
SHS Exposure % (n)				
Yes	52.6% (10)	48.7% (19)	28.6% (18)	**X^2=7.192, df=2**
No	36.8% (7)	51.3% (20)	71.4% (45)	**p=0.027**
Missing	2	0	0	

5.7.0 Multinomial Logistic Regression with Motor Proficiency and Attention-Deficit Hyperactivity Disorder

Multinomial logistic regression was used to explore the secondary objective of this study. In model 1, the odds ratio was first calculated for SHS exposure and moderate-high risk DCD (with and without ADHD) to provide an unadjusted measure of association for the effect of SHS exposure on DCD in the presence and absence of ADHD (see Table 5.7). SHS exposure in utero was found to be a significant predictor of moderate-high risk DCD when ADHD was present (p=0.025) and not present (p=0.042). Therefore, children exposed to SHS in utero were more likely than those not exposed, to develop moderate-high risk DCD in the presence or absence of ADHD. The odds of a

child with ADHD developing moderate-high risk DCD when exposed to SHS in utero were 3.57 times greater than the odds for a child not exposed to SHS in utero. The odds of a child without ADHD developing moderate-high risk DCD when exposed to SHS in utero was slightly lower at 2.38 times greater than the odds for a child not exposed to SHS in utero. After adjusting for age, sex, birth weight, premature birth, and household income in model 2, the effect was no longer significant for both groups.

5.7. The association between SHS exposure in utero and moderate-high risk DCD (with and without ADHD) by multinomial logistic regression analysis

	Moderate-high risk DCD (≤15th %ile) **w/** ADHD				Moderate-high risk DCD (≤15th %ile) **w/o** ADHD			
	Model 1		Model 2		Model 1		Model 2	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
SHS Exposure	**3.57 (1.18-10.34)**	**0.025**	3.17 (0.88-11.42)	0.078	**2.38 (1.03-5.46)**	**0.042**	1.96 (0.76-5.06)	0.164
Age			1.37 (0.39-4.79)	0.626			1.47 (0.56-3.83)	0.435
Sex			1.26 (0.37-4.34)	0.717			0.95 (0.38-2.37)	0.915
Birth Weight			0.61 (0.18-2.05)	0.427			1.50 (0.63-3.57)	0.363
Premature Birth			0.56 (0.04-8.08)	0.672			2.55 (0.41-15.84)	0.315
Household Income			0.79 (0.50-1.25)	0.306			0.85 (0.63-1.16)	0.305

Chapter 6: Discussion

6.1.0 Introduction

The primary objective of this study was to examine the effect of SHS exposure in utero among children with DCD. The secondary objective was to examine the change in effect when comparing children with DCD, children with comorbid DCD and ADHD, and TD children. It was hypothesized that there would be a positive association between SHS exposure in utero and the occurrence of DCD; and further, that there would be a greater association for those with comorbid DCD and ADHD. Consistent with the hypothesis and the limited research available on this topic, the findings of this study supported a link between SHS exposure in utero and DCD.

6.2.0 Smoke Exposure during Pregnancy and Developmental Coordination Disorder

Smoke exposure in utero for children with moderate risk and high risk DCD was compared with that of TD children. Significant differences for SHS exposure were found in both the moderate risk and high risk DCD groups, thus children in both groups were significantly more likely to have been exposed to SHS in utero. Further analysis found SHS exposure in utero to be a significant predictor of high risk DCD, even after adjusting for age, sex, birth weight, premature birth, and household income. Given that children in the high risk DCD group had significantly greater odds of developing DCD when exposed to SHS in utero, it is plausible to assume a dose-response relationship between maternal SHS exposure during pregnancy and DCD. Dose-response relation is one of nine criteria used to evaluate evidence for causality, according to the well-known

Bradford-Hill criteria (Bradford-Hill, 1965). As defined by Bradford-Hill (1965), dose-response relation exists when an increase in exposure is associated with an increase in risk of an outcome. The findings of an association between high risk DCD and SHS exposure in utero, and the possibility of a dose-response in this relationship, supports the hypothesis that SHS exposure in utero may be a risk factor for DCD in children.

The finding of increased SHS exposure in utero among children with high risk DCD is in line with findings from the few studies that have investigated maternal smoking during pregnancy and physical control and coordination in offspring (Cornelius et al., 2001; Larsson & Montgomery, 2010; Trasti et el., 1999). These studies also found a positive association between maternal smoking during pregnancy and decreased motor coordination in children. As previously noted, these studies did not assess nor diagnose DCD and only investigated active smoke exposure during pregnancy.

While active smoke exposure is of importance, passive smoke exposure is also relevant. Research shows that many of the carcinogens and toxic chemicals in mainstream smoke are also found in SHS (National Research Council, 1986). In fact, higher levels of certain toxic chemicals such as ammonia, nitrogen oxides, and the volatile N-nitrosamines have been found in SHS compared to mainstream smoke (IARC, 2002; National Research Council, 1986). Another important issue is that SHS exposure is often difficult to control as it is not based on voluntary behaviour. Substantial progress has been made to control SHS exposure in public areas and the workplace; however, a place of concern remains within the home. Home smoking restrictions are private household rules and are voluntary to the members within the household. The only approach that

effectively protects non-smokers from SHS exposure is a rule making the home completely smoke-free (Levy, Romano & Mumford, 2004). It is important to reduce or eliminate SHS exposure within the home because the home is a major source of exposure for children and for those non-smoking adults who are not exposed elsewhere. This study is not only one of the first to investigate the effects of SHS exposure in utero on the occurrence of DCD, but also provides further supporting evidence of the need to eliminate all sources of SHS exposure, especially within the home.

6.3.0 Smoke Exposure during Pregnancy and Developmental Coordination Disorder along with Attention-Deficit Hyperactivity Disorder

When compared to TD children, SHS exposure in utero was found to be a significant predictor of moderate-high risk DCD, whether on its own or in combination with ADHD. As hypothesised, children with comorbid DCD and ADHD had a greater risk for developing moderate-high risk DCD when exposed to SHS in utero. This association was no longer significant when adjusting for age, sex, birth weight, premature birth, and household income. Each of these factors were tested separately to see which factor(s), if any, eliminated the effect of SHS exposure on the occurrence of moderate-high risk DCD (with and without ADHD). Household income eliminated the effect of SHS exposure in both groups, and birth weight eliminated the effect in the moderate-high risk DCD without ADHD group. The household income variable was categorized into 6 groups and when differences between groups were tested for this variable, there were 8 cells with an expected count less than 5. Therefore, it could have been sample size, and

not household income itself, that eliminated the effect of SHS exposure in utero; this study did not have sufficient power to detect a significant difference. For birth weight, this factor eliminated the effect of SHS exposure in utero for the moderate-high risk DCD only group. Low birth weight is a known risk factor for DCD as seen through many studies investigating this relationship (Hands, Kendall, Larkin, Rose & Parker, 2009; Hua et al., 2014; Zwicker et al., 2013). Considering birth weight eliminated the effect of SHS exposure in the model, one could speculate that SHS exposure in utero and low birth weight have a shared effect. Given this, previous studies investigating low birth weight on DCD might have over-estimated the effect by not accounting for maternal smoke or SHS exposure during pregnancy.

DCD and ADHD are two of the more prevalent neuro-developmental disorders and they may be related through common causal pathways. Prior research has already demonstrated the possible link between SHS exposure in utero and the occurrence of ADHD in children. Similar research in the area of DCD has not yet been conducted. Given that DCD and ADHD are highly comorbid, it was reasonable to assume that SHS exposure in utero could also be a risk factor for DCD. The findings of this study confirm this assumption, and are consistent with the limited findings that currently exist. Landgren and colleagues (1998) found an independent effect of maternal smoking during pregnancy on the development of DAMP, which includes deficits in both attention and motor control. There were several limitations with the study in that the researchers did not specifically assess and diagnosis DCD using the DSM-5 criteria, and they did not look at the deficits of attention and motor control separately. To date, there has been no published

research examining maternal SHS exposure during pregnancy and children with DCD comorbid with ADHD. This is a significant gap in literature given the comorbidity rates of DCD and ADHD. This study addressed this gap by measuring both DCD and ADHD, and by investigating the relationship between SHS exposure in utero on each disorder separately and together. Finding SHS exposure in utero to be a significant predictor of moderate-high risk DCD, whether on its own or in combination with ADHD, causes one to question those studies of children with ADHD, who were not assessed for DCD, and the significant association with SHS exposure in utero. It is possible that the positive associations found could be due to DCD being present. It would be of interest to test this hypothesis by using a nested case-control design performed within the context of a prospective cohort study. The study would start during pregnancy and would track children until the age of diagnosis for both DCD and ADHD. This would allow for more intricate measures of maternal smoke exposure during pregnancy (both active and passive), as well as, incorporating appropriate measures to assess and diagnosis both DCD and ADHD following the DSM-5 diagnostic criteria.

6.4.0 Baseline Characteristics between Developmental Coordination Disorder Groups

No significant differences were found between DCD groups in relation to the baseline characteristics which included age, sex, birth weight, premature birth, and household income. These findings are inconsistent with the results of other studies that have found DCD to be significantly more prevalent in boys, and more prevalent in children born preterm and with low birth weight (Hands, Kendall, Larkin, Rose, &

Parker, 2009; Hua et al., 2014; Zwicker et al., 2013). This could be explained by the fact that data for this study was not derived from a random sample of students within this age range. Another possibility is sample size and that there was not sufficient power to detect a significant difference. In terms of DCD being more prevalent in boys, although some research does suggest this, these findings might be a result of bias in detection that favors boys and disadvantages girls (Kirby et al., 2014). Other studies using school-based samples have also found no differences in the prevalence of DCD between boys and girls (Dewey, Kaplan, Crawford & Wilson, 2002). The findings from this study could also explain that while gender, premature birth, and low birth weight are all known risk factors for DCD, there are still other factors at play.

6.5.0 Study Limitations

While this study presented important and novel findings, several limitations need to be acknowledged and addressed. First, children were referred as having high risk DCD, moderate risk DCD, or moderate-high risk DCD because it was not tested whether these children met the full diagnostic criteria of the DSM-5. It was not assessed if disturbances in criterion A significantly and persistently interfered with activities of daily living or academic achievement (criterion B). Although this is not uncommon in other studies (Visser, 2003), future work should include an assessment of the impact motor coordination problems have on normal activities of daily living. Even though criterion B of the DSM-5 criteria for DCD was not directly evaluated in this study, children with other medical diagnoses were not included, a measure of IQ was obtained, and a common

standardised measure of motor impairment was used to fulfill the other diagnostic criteria for DCD. Also, many research studies done in this population of children have used only an assessment of motor ability to identify children with DCD (e.g., Cairney et al., 2005a; Faught et al., 2005; Schott et al., 2007; Visser, 2003). A second limitation is that children were identified with ADHD by the use of the CPRS-R:S in which a parent answered questions about their child. Typically, the process of interpreting the CPRS-R:S tool, when used to diagnose ADHD, requires the integration of information from multiple sources such as parents, teachers, and expert physicians. Considering only the parents' perspective was obtained in this study, identification of children with ADHD should be considered preliminary and not a diagnosis.

Another limitation to this study was the definition of maternal SHS exposure. Mothers' were asked if they were exposed to SHS on a regular basis in which regular basis was not defined. Furthermore, maternal SHS exposure was broadly categorized as "exposed" or "not exposed." Information on frequency, quantity, and patterns or types of exposure, were not collected. A broad categorization such as this may mask the effect of low-level exposure, and also restricts important information on potential dose-response. In addition, this study relied on maternal reports of smoke exposure during pregnancy. This poses a problem with recall bias, and also with underreporting to avoid possible negative reactions to the social undesirability of smoking or being exposed to smoke during pregnancy. If underreporting did occur, the strength of the effect of maternal SHS exposure on DCD is likely, if anything, to be an underestimate of the true association.

6.6.0 Future Considerations

Notwithstanding the limitations of this study, this was one of the first studies attempting to examine the effects of SHS exposure in utero on the occurrence of DCD in children. SHS exposure in utero appears to be predictor of DCD, and while SHS exposure during pregnancy may not be the root cause of DCD, it does appear to be a contributor for this problematic developmental disorder. Further research is required to replicate these study findings with varying study populations, and also to overcome the aforementioned limitations.

Experimental and longitudinal studies are the most appropriate for understanding cause and effect. For this context, an experimental design would not be useful as it would not be ethical to expose women to smoke during pregnancy and wait to observe the consequences. Therefore, a nested case-control design performed within the context of a prospective cohort study would be optimal to allow for direct measurement of exposure and outcome. Measures should include a detailed demographic and health survey covering a broad array of questions around pregnancy and delivery, as well as, the frequency, quantity, and patterns or types of smoke exposure during pregnancy. Following mothers throughout their pregnancy would avoid recall bias, as well as, allow the opportunity to capture tobacco exposure through the use of biological markers. Cotinine is a major metabolite of nicotine that can be used as a marker for active smoking and as an index for passive smoking. Cotinine is most often preferred over nicotine because of its substantially longer half-life. The estimated half-life of cotinine in plasma is about 15-20 hours where the half-life of nicotine is only 0.5-3 hours (Kyerematen,

Morgan, Chattopadhyay, deBethizy, & Vesell, 1990). Cotinine can be measured in serum, urine, or saliva with the half-life being the same in all three fluids (Jarvis, Russell, Benowitz, & Feyerabend, 1988). Cotinine concentrations tend to be higher in urine than in serum; however, serum is most suitable when requiring a quantitative assessment of exposure (Watts, Langone, Knight, & Lewtas, 1990). Therefore, serum should be the method of choice in future studies. Lastly, future studies should ensure that all diagnostic criteria for DCD are met in order to confirm the presence or absence of DCD.

6.7.0 Final Thoughts

DCD is a highly prevalent and chronic neuro-developmental condition that is most often unrecognized. Given the significant number of children affected by this condition, it is essential that we better understand the etiology of DCD to reduce the current prevalence rates. The cause of DCD is also important to determine in order to put necessary and appropriate preventative measures in place. This study was one of the first to look at the possible relationship between SHS exposure in utero and DCD. The findings from this study further highlight the negative effects that prenatal exposure to tobacco has on a developing fetus. These findings may guide future strategies to improve maternal health, and more specifically, the prevention of smoking or exposure to smoke during pregnancy. This could potentially lead to a reduction in the rate of DCD in the general population.

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Appendix A: PHAST I Research Ethics Approval

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

Appendix B: PHAST II Research Ethics Approval

DATE: January 10, 2008

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

TO: Brent FAUGHT, CHSC

FILE: 07-106 FAUGHT

TITLE: Establishing the Health Profile of Children with Motor Coordination Challenges

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

DECISION: Accepted as Clarified

This project has received ethics clearance for the period of January 10, 2008 to December 30, 2011 subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The clearance period 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 cleared by the REB. During the course of research no deviations from, or changes to, the protocol, recruitment, or consent form may be initiated without prior written clearance from the REB. The Board must provide clearance for any modifications before they can be implemented. If you wish to modify your research project, please refer to http://www.brocku.ca/researchservices/forms to complete the appropriate form 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 clearance 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 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 *Continuing Review/Final Report* is required.

Please quote your REB file number on all future correspondence.

Office of Research Ethics, MC D250A
Brock University
Office of Research Services
500 Glenridge Avenue
St. Catharines, Ontario, Canada L2S 3A1

Appendix C: Informed Consent

CHILD LETTER OF INFORMED CONSENT

Principal Investigators: Dr. John A. Hay, Brock University
Dr. John Cairney, University of Toronto & Brock University
Dr. Brent E. Faught, Brock University

Dear Parent and Child:
Thank you for your interest in our study. Please read the following information together. If you both feel comfortable and willing to participate in the tests described below, please check the boxes at the end of this consent form indicating child and parent consent.

Purpose: The purpose of this study is to look at healthy growth and development of children for the next three years.

Procedures: This assessment will take approximately 2.5 to 3 hours long and is divided into three parts. We thank you for participating. As promised, we have agreed to provide transportation for you to and from Brock University as well as $50 for your family's participation in this study. Your participation is voluntary and you are free to withdraw from this study at any time without penalty from Brock University. Further, you are under no obligation to answer any or all questions or to participate in any aspect of this project. If you wish to stop participating in this study at any time, you and your parent will still receive free transportation from us as well as $50 for your participation in the laboratory. Each part is described below.

PART I
This part of the study will be conducted in our laboratory at Brock University and requires 2.5 to 3 hours of your time. First, we would like you to complete the following forms, which will take about 10 minutes.

1. Medical Screening Questionnaire
2. Edinburgh Survey – Handedness Questionnaire

Next, we would like to complete a number of physical assessments on your child with the parent/guardian present. These assessments include:

1. **Body composition:**
    a. Height and weight will be measured using a dual purpose stadiometer.
    b. 9 skinfold sites using painless pinch calipers. (It does not hurt).
    c. Measure around the waist and hip using a flexible tape measure.
    d. Bioelectric impedence analysis requires your child to stand on a weight scale and grasp handles. An electrical impulse travels from your child's hands to their feet. The impulse cannot be felt and causes no harm.
    e. Lengths of your child's ring and index fingers.
    f. Body muscle and fat weight will be measured while your child sits in the BOD POD chamber. If your child expressing previous or current anxiety for confined spaces, they will not be allowed to participate in this portion of the study. The BOD POD incorporates a built in window on the front of the chamber in the event of a claustrophobic event or for communication purposes as well as a safety latch on the inside of the chamber for the subject to voluntarily exit on their own.

During this 5-minute assessment, your child will be asked to relax and breathe normally.

2. **Cardiovascular health measures:** The carotid ultrasound method will be performed using a probe and pen like-devices. Heart rate will be measured using sensors placed on the skin of your child's chest. These sensors are used to detect the electrical activity generated by the heart and are not used to transmit electrical signals into their body from the heart rate monitor. Blood pressure is monitored using an automated arm cuff system that is similar to the method used in a doctor's office. A cuff is wrapped around the upper arm and is inflated then deflated. No risk is involved.
3. **Movement ABC^2 assessment:** This motor coordination assessment involving 8 short activities, including tasks such as tracing, cutting on a line and throwing a ball.
4. **Physical fitness assessment:** This assessment uses a bicycle to measure the maximum amount of heavy exercise. The bicycle tension will gradually get more difficult to pedal. A mask over the mouth and nose will be used to collect oxygen and carbon dioxide. The assessment will be finished when your child decides. One of the common risks of this kinds of assessments is the brief sensation of exhaustion. At the end of the assessment, your child will be asked to continue to pedal the bicycle at a very easy level until this sensation goes away. The risk of serious illness or death is extremely rare and is reduced by completing the medical screening questionnaire before the assessment and the continuous monitoring we will perform during the assessment.
5. **Accelerometer assessment:** This assessment will require your child to wear a small box the size of a smaller pager clipped onto their pant waist. The accelerometer is designed to measure activity movement that your child performs. We wish for your child to wear the accelerometer from the time they wake up, until the go to bed at night for 7 days. We also ask that the parent complete the Habitual Activity Estimation Scale and our Activity Log. There is no risk associated with this assessment. We will make arrangements to pick the accelerometer unit at your home.

PART II

The second part of the study would take place approximately 7 days from now at your home. We would come in the morning (before your child has breakfast) and it will only take about 10 minutes. We wish to collect a sample of your child's blood using a finger pinprick technique. The middle finger of your child's non-dominant hand (e.g. if they are right handed, we will use the middle finger of their left hand) will be pricked so two drops of blood can be sampled. Your child will feel a small prick, but will not feel any pain or discomfort for the remainder of the assessment. The tip of that finger may feel sensitive and a little bit sore for about a day. It is important to keep the site clean and covered with an adhesive bandage until it is healed to reduce the risk of infection. We will also use this moment to pick up the accelerometer that you will have had for the past week.

PART III

For this part of the study we would like you to allow your child's homeroom teacher complete a survey on your child's combined listening, speaking, reading, writing, mathematics and reasoning skills. The name of this survey is the Learning Disabilities Diagnostic Inventory. Despite the name of this survey, we are not looking to diagnose any disabilities in your child's learning ability, nor is the teacher expected to provide a learning disabilities' diagnosis. We simply wish to see how able your child is while learning at school. The results of this assessment will not be shared with your child's school.

Participation and Withdrawal: Your child's participation is voluntary and they are free to withdraw from this study at any time without penalty from Brock University. Further, your child is not required to answer any or all questions or to participate in any aspect of this project.

Confidentiality: All personal data will be kept strictly confidential and all information will be coded so that your child is not associated with their answers. Only the researchers named above will have access to the complete data. Any information we receive will be entered immediately into computer records using a code number with no name attached. It is our intent to continue to publish the results of this research in scientific journals. Again, no personal information will be identified or be possible within any publication.

Information: This study has been reviewed and approved by the Brock University Research Ethics Board, (File#: 07-106) Research Services, Brock University, Room C315 - 905-688-5550 (Ext. 4315). We greatly appreciate your co-operation. If you would like to receive more information about the study, please contact **Dr. Brent E. Faught** at 905-688-5550, (Ext. 3586). If you are willing to grant permission to participate in this study, please complete the consent form below.

Thanks for your help!

Brent E. Faught, Ph.D. John A. Hay, Ph.D. John Cairney, Ph.D.

PARENT CONSENT FORM

I have read and understand the above explanation of the purpose and procedures of the project. My questions have been answered to my satisfaction.

- ☐ I give permission for my child to participate in **Part I** of the Brock University study conducted by Dr. John Hay, Dr. John Cairney and Dr. Brent E. Faught.
- ☐ As the participating child, I wish to participate in **Part I** of the Brock University study conducted by Dr. John Hay, Dr. John Cairney and Dr. Brent E. Faught.
- ☐ I give permission for my child to participate in **Part II** of the Brock University study conducted by Dr. John Hay, Dr. John Cairney and Dr. Brent E. Faught.
- ☐ As the participating child, I wish to participate in **Part II** of the Brock University study conducted by Dr. John Hay, Dr. John Cairney and Dr. Brent E. Faught.
- ☐ I give permission for my child to participate in **Part III** of the Brock University study conducted by Dr. John Hay, Dr. John Cairney and Dr. Brent E. Faught.
- ☐ As the participating child, I wish to participate in **Part III** of the Brock University study conducted by Dr. John Hay, Dr. John Cairney and Dr. Brent E. Faught.

OR

- ☐ I do **NOT** give permission for my child to participate in the Brock University study conducted

by Dr. John Hay, Dr. John Cairney and Dr. Brent E. Faught.

☐ As the participating child, I do **NOT** wish to participate in the Brock University study conducted by Dr. John Hay, Dr. John Cairney and Dr. Brent E. Faught.

Signature of Parent/Guardian: _____ Date: _____

Signature of Student: _____ Date: _____

Appendix D: Data Collection Form

ADVANCED HEATLH ASSESSMENT INFORMATION SHEET

Date: _____ Time (am/pm): _____

SECTION 1: STUDENT INFORMATION		
Student ID #: ___ ___ ___ ___ ___ ___ ___ ___ ___	**Name:**	
Gender: Male Female	**DOB:** __ __ / __ __ / __ __ __ __ (month) (day) (year)	**Age:** _____
Height (cm): _____ **cm**	**Weight (kg):** _____ **kg**	**BMI:** _____ **(kg/m^2)**

SECTION 2: CONSENTS and QUESTIONNAIRES	
STUDENT (check for completeness)	**PARENT (check for completeness)**
1. Consent (signed): _____	1. Consent (signed): _____
2. Medical Screening Questionnaire: _____	2. Medical Academic History Questionnaire: _____
3. Edinburgh Survey: _____	3. Conner's Parent Rating Scales: _____
4. Tanner Questionnaire: _____ OR complete at home: _____	4. Edinburgh Modified Parent Survey: _____
5. Accelerometer and Pkg (given) : Y _____ N (no consent) _____	5. Habitual Activity Estimation Scale: _____
6. Teacher Package (given) : Y _____ N (no consent) _____	6. Hypermobility Questionnaire: _____
7. Tanner Questionnaire Completed: Y _____ N _____	7. Accelerometer Log Completed: Y _____ N _____
8. "Two Days in My Life" Completed: Y _____ N _____	8. "Two Days in My Child's Life" Completed: Y _____ N _____
9. Teacher Package Completed: Y _____ N _____	9. Consent and Questionnaires Filled Out By: _____
Comments:	

SECTION 3: BODY COMPOSITION MEASURES	
Waist Circumference	**Hip Circumference**
Examiner:	
Trail #1: _____ **cm**	Trail #1: _____ **cm**
Trail #2: _____ **cm**	Trail #2: _____ **cm**
Mean: _____ **cm**	Mean: _____ **cm**
Waist / Hip Ratio and Percentage	
Ratio: _____	Percentage: _____
Bioelectric Impedence Analysis	
Examiner:	
Lean Body Mass: _____ **kg**	Percent Body Fat: _____ %
Body Fat Mass: _____ **kg**	Basal Metabolic Rate: _____ kcal

SECTION 3 CONTINUED: BODY COMPOSITION MEASURES				
Skinfold Measurements				
Examiner:				
SITE	**TRIAL 1 (mm)**	**TRIAL 2 (mm)**	**TRAIL 3 (>1mm)**	**MEAN (mm)**
BICEPS				
TRICEPS				
CHEST				
SUBSCAPULAR				
MID-AXILLARY				
SUPRA-ILIAC				
ABDOMEN				
THIGH				
MEDIAL CALF				
SUM OF SKIN FOLDS: _____ **(mm)**				

PERCENT BODY FAT (3 site – Jackson and Pollock): _____ **(%)**	
PERCENT BODY FAT (4 site – Durnin and Wormersley): _____ **(%)**	
PERCENT BODY FAT (7 site – Jackson and Pollock): _____ **(%)**	
BOD POD	
Examiner:	
Fat Mass: _____ **kg**	Percent Body Fat**:** _____ **%**
Fat Free Mass: _____ **kg**	Body Volume**:** _____ **L**
Body Mass: _____ **kg**	Body Density**:** _____ **kg/L**
Thoracic Gas Volume**:** _____ **L**	
Digits	
Examiner:	
RIGHT HAND	**LEFT HAND**
Digit #2 (pointer finger): _____ **(mm)**	Digit #2 (pointer finger): _____ **(mm)**
Digit #4 (ring finger): _____ **(mm)**	Digit #4 (ring finger): _____ **(mm)**
Right Hand Ratio (D2/D4): _____	Left Hand Ratio (D2/D4): _____

SECTION 4: ARTERIAL MEASUREMENTS	
Doppler Settings	
Examiner:	
Frequency: 10.0 mHz	Power: 0 dB
Depth: _____ **cm**	
FPS: change focus # (decrease to 2) to increase fps	Persistence: turn to minimum

Blood Pressure - Manual		
	Systole (mmHg)	**Diastole (mmHg)**
Pre 1		
2		

3		
Post 1		
2		
3		

Distance Measurements	
Sternal notch to toe: **_____ cm**	Sternal notch to carotid: **_____ cm**

Notes for Cardiovascular Component

SECTION 5: LEFT VENTRICULAR MASS MEASUREMENTS	
Examiner:	
Probe: **_____**	Depth: **_____ cm**
B-Mode Images:	M-Mode Images:
Interventricular Septum (end-distole): _____	Ejection Fraction: _____

Left Ventricular Diameter (end-diastole): _____	Circumferential Shortening: _____
Posterior Wall (end-diastole): _____	LVM: _____
Left Ventricular Diameter (end-systole): _____	

SECTION 6: VO_2 MAX	
Examiner:	
Bike Instructions	
RPM: 60 – 80 rpm	Begin Test: 20 watts
Increment Changes: 20 watt increase every 2 minutes	Finish Test: volitional drop out; heart rate reaches max (220-age), expiratory ratio is ≥ 1.1, or of the VO_2 peak plateaus
Heart Rate	
Rest: **_____ bpm**	_____W: **_____ bpm**
_____W: **_____ bpm**	_____W: **_____ bpm**
_____W: **_____ bpm**	_____W: **_____ bpm**
_____W: **_____ bpm**	_____W: **_____ bpm**
_____W: **_____ bpm**	_____W: **_____ bpm**
Final VO_2: **_____ ml/kg**	
MAX Heart Rate: **_____ b/min**	Final Duration: **_____ min**
Watts: **_____ W**	Final Stage: **_____**
Final RER: **_____**	Last RPE Report: **_____**
Notes: (Please note any changes to protocol, problems during testing, medical conditions that would hinder test results)	
SECTION 7: BLOOD ANALYZER	

TC: _____ **mg/dL**	Non-HDL: _____ **mg/dL**
HDL: _____ **mg/dL**	TC/HDL: _____ **mg/dL**
TRG: _____ **mg/dL**	GLU: _____ **mg/dL**
LDL: _____ **mg/dL**	GLU: _____ **mmol/L**
Notes: (Please note any changes to protocol, problems during testing, other circumstances that would hinder test results)	

EXTRA MEASURMENTS:	
Section 4 Continued: Arterial Measurements	
Diastolic Diameter: _____ **mm**	Heart Rate: _____ **bpm**
Systolic Diameter: _____ **mm**	Automated Systolic Arterial Pressure: _____ **mmHg**
Diameter Change: _____ **mm**	Automated Diastolic Arterial Pressure: _____ **mmHg**
Carotid Pulse Pressure: _____ **mmHg**	Mean Arterial Pressure: _____ **mmHg**
Compliance: _____ **mm/mmHg**	Automated Pulse Pressure: _____ **mmHg**
Distensibility: _____ **%**	
Section 5 Continued: Left Ventricular Mass Measurements	
End Diastolic Volume: _____ **ml**	Stroke Volume: _____ **ml**
End Systolic Volume: _____ **ml**	LMVbsa: _____ **g/m^2**

EQUATIONS:

Compliance (mm/mmHg): $\frac{\text{Diameter Change (mm)}}{\text{Carotid Pulse Pressure (mmHg)}}$

Distensibility (%): $\frac{\text{Diameter Change (mm)}}{\text{Diastolic Diameter (mm)}} \Big/ \text{Carotid Pulse Pressure (mmHg)} * 100\ \%$

Diameter Change (mm): Systolic Diameter – Diastolic Diameter

Mean Arterial Pressure (mmHg): Diastolic Blood Pressure + 0.33 (Systolic Blood Pressure – Diastolic Blood Pressure)