A DEVELOPMENTAL PERSPECTIVE OF THE ENVIRONMENTAL STRESS HYPOTHESIS

A DEVELOPMENTAL PERSPECTIVE OF THE RELATIONSHIP BETWEEN DEVELOPMENTAL COORDINATION DISORDER AND INTERNALIZING PROBLEMS BASED ON THE ENVIRONMENTAL STRESS HYPOTHESIS

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LAY ABSTRACT

Developmental Coordination Disorder (DCD) or poor motor coordination has been linked to the higher levels of internalizing problems, such as anxiety and/or depression. However, the underlying mechanisms remain unclear. Although the Environmental Stress Hypothesis (ESH) provides a theoretical framework illustrating that physical and psychosocial consequences of DCD may play important roles, this model has not been comprehensively examined. Therefore, this dissertation tested different components of the ESH in three age groups (i.e., preschool age, school age, and young adulthood) in an attempt to provide a better understanding of why motor difficulties cause more internalizing problems from a developmental perspective. Findings confirm that children with DCD and adults with poor motor coordination are at greater risk for internalizing problems, and that perceptions of self may play a more important role explaining the relationship. However, the potential pathways from motor difficulties to internalizing problems may differ by sex and age. In summary, it is recommended that, in order to prevent or improve mental health problems, interventions should target improvements in self-concept, such as self-esteem, through participation in physical activity or weight control, while taking into account sex and age.

ABSTRACT

The Environmental Stress Hypothesis (ESH) illustrates the underlying mechanisms of internalizing problems in children with Developmental Coordination Disorder (DCD), indicating that the relationship between DCD and internalizing problems could be influenced by numerous physical and psychosocial consequences. However, the potential pathways described in this conceptual framework have not been comprehensively examined. Furthermore, given that child development is a dynamic process, these pathways have not been investigated from a developmental perspective. In order to address these gaps in knowledge, this dissertation sought to advance our understanding of the ESH by examining the underlying mediating pathways connecting DCD and internalizing problems in three age groups: early childhood, late childhood/early adolescence, and young adulthood.

Study 1 showed that preschool children at risk for DCD (rDCD) experience more internalizing problems than typically developing children. However, physical activity and BMI do not mediate the relationship between rDCD and internalizing problems. Overall, our findings confirm that rDCD and internalizing problems co-occur in early childhood. Nevertheless, as there is no mediation of physical activity or BMI, the underlying mechanisms may be more related to other psychosocial outcomes (e.g., self-concept or perceived social support), suggested in the ESH.

Study 2 examined school-aged children and included global self-worth, one of the psychological outcomes identified in the ESH, to address one of the limitations in Study 1. Findings support the ESH by showing a sequential mediating pathway from probable DCD (pDCD), through physical activity/BMI and global self-worth, to self-reported internalizing problems. Sex was found to moderate the underlying mechanisms of internalizing problems, altering the pathways from pDCD to internalizing problems.

Study 3 was conducted to test the full ESH in emerging adults. Results support the mediating effects of psychosocial well-being, including stress, global relationships, perceived social support, and self-concept, on the relationship between poor motor coordination and self-reported psychological distress in young adults. However, in this age group, physical inactivity and higher BMI, did not mediate the relationship between motor coordination and internalizing problems.

In conclusion, this dissertation highlights the co-occurrence of motor difficulties and internalizing problems across three developmental stages. The underlying mechanisms of internalizing problems may differ by age and sex. It is also worth noting that compared to physical health, psychosocial well-being may play a more important role as a mediator in the relationship between motor coordination and internalizing problems.

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LIST OF ABBREVIATIONS

ADC	Adult DCD/Dyspraxia Checklist
ADHD	Attention Deficit/Hyperactivity Disorder
BMI	Body Mass Index
CATCH	Coordination and Activity Tracking in CHildren
CO-OP	Cognitive Orientation to Daily Occupational Performance
DCD	Developmental Coordination Disorder
pDCD	Possible/Probable DCD
rDCD	At risk of DCD
DSM	Diagnostic and Statistical Manual of Mental Disorder
ESH	Environmental Stress Hypothesis
GR	Global Relationships
ICD	International Statistical Classification of Diseases and Related Health Problems
ICF	International Classification of Functioning, Disability and Health
IPAQ	International Physical Activity Questionnaire
MABC	Movement Assessment Battery for Children
MSPSS	Multidimensional Scale of Perceived Social Support
PHAST	Physical Health and Activity Study Team
PQ	Participation Questionnaire
PSS	Perceived Social Support
SEM	Structural equational modeling
SO	Significant other
SPPC	Harter's Self-Perception Profile for Children
SPSS	Statistical package for the social sciences
TD	Typically developing

PREFACE
DECLARATION OF ACADEMIC ACHIEVEMENT

This thesis is prepared in the "sandwich" format as outlined in the School of Graduate Studies' Guide for the Preparation of Theses. It includes a general introduction, three independent studies prepared in journal article format, and a general discussion. The candidate is the first author on all of the manuscripts. At the time of the thesis preparation, the manuscripts of Chapter 2, 3, and 4 were completed. Chapter 3 and 4 were prepared to submit. As Chapter 2 was analyzing preliminary data, the results will be updated once the data collection is finished.

CONTRIBUTION TO PAPERS WITH MULTIPLE AUTHORSHIP

Chapter 2 (Study 1)

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Y. C. Li's role in Study 1:

- Conceived the research question
- Lead investigator responsible for data analysis and interpretation
- Primary author of manuscript

Role of co-authors in Study 1:

- MYWK was a co-investigator on the CATCH study
- MYWK provided critical feedback on previous drafts of the manuscript
- CR and SKD made remarkable contribution to the data collection and data preparation for analysis
- CAM, BWT, and JC were principle investigators on the CATCH study and obtained funding
- JC assisted YCL with the analysis and interpretation of the data
- JC provided critical feedback on previous drafts of the manuscript
- JC revised the article and approved of the final version of the manuscript

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Y. C. Li's role in Study 2:

- Conceived the research question
- Lead investigator responsible for data analysis and interpretation
- Primary author of manuscript

Role of co-authors in Study 2:

- MYWK provided critical feedback on previous drafts of the manuscript
- HC assisted YCL with the analysis and interpretation of the data
- JH, BF, and JC were principal investigators on the PHAST project and obtained funding
- JC assisted YCL with the analysis and interpretation of the data
- JC provided critical feedback on previous drafts of the manuscript
- JC revised the article and approved of the final version of the manuscript

Chapter 4 (Study 3)

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Y. C. Li's role in Study 3:

- Conceived the research question and study design
- Author of ethics application at McMaster University
- Contributed to study design and measure selection
- Lead investigator responsible for data collection, analysis and interpretation
- Primary author of manuscript

Role of co-author in Study 3:

- MYWK provided critical feedback on study design and previous drafts of the manuscript
- JC provided feedback about the study design and obtained funding
- JC assisted YCL with obtaining ethics approval at McMaster University
- JC assisted YCL with the analysis and interpretation of the data
- JC provided critical feedback on previous drafts of the manuscript

CHAPTER 1:

INTRODUCTION

1.1 DEVELOPMENTAL COORDINATION DISORDER

This dissertation is about children with Developmental Coordination Disorder (DCD), one of the most common neurodevelopmental disorders in childhood. It is also about young adults, who have difficulties with motor coordination that are consistent with the diagnoses of DCD. The dissertation is guided by the Environmental Stress Hypothesis (ESH) to investigate the relationships among DCD (and motor coordination as a continuous variable), physical and psychosocial health, and internalizing problems. In order to set the context for this dissertation, we begin with the introduction of DCD, including the definitions, epidemiology and etiology, clinical features, and prognosis. Next, we will review the literature on internalizing problems in children and youth, and discuss the research specific to DCD. Finally, we will review the ESH in detail, providing the specific context for the studies contained in this dissertation.

1.1.1 Definitions

While the term DCD was first introduced in 1987 in the *Diagnostic and Statistical Manual of Mental Disorder, Third Edition (DSM-III)*, several other terms had been used before to describe the same group of children with substantial motor impairments: Disorder of Attention and Motor Performance, Dyspraxia, Minimal Neurological Dysfunction, or physical awkwardness (Henderson & Henderson, 2003), are some examples. In order to solve the terminological ambiguity, a group of experts gathered at the London Consensus

Forum in Canada in 1994 and reached the agreement that DCD would be a more appropriate term reflecting the nature of this disorder and should be widely used across different disciplines (Henderson & Henderson, 2003).

Both the *International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10)* (WHO, 2007b) and the *DSM, Fifth Edition (DSM-V)* (APA, 2013) outline broad diagnostic criteria for the disorder. In the ICD-10, DCD, along with clumsy child syndrome and developmental dyspraxia, are subsumed under the heading Specific Developmental Disorder of Motor Function, and defined as "*a disorder in which the main feature is a serious impairment in the development of motor coordination that is not solely explicable in terms of general intellectual retardation or of any specific congenital or acquired neurological disorder…… marked neurodevelopmental immaturities such as choreiform movements of unsupported limbs or mirror movements and other associated motor features, as well as signs of impaired fine and gross motor coordination*" (WHO, 2007b). Children with abnormalities of gait and mobility (e.g., ataxic gait or paralytic gait), lack of coordination (e.g., unspecified ataxia), and mental retardation, however, should be excluded from the diagnosis.

According to the London Consensus Forum and the Leeds Consensus Statements (Sugden, Chambers, & Utley, 2006), the definitions for DCD provided by the DSM – 4th edition – Text Revision have been accepted as the most suitable diagnostic criteria (APA, 2000), despite the fact that the ICD-10 may be used in some European countries due to its legal status (Blank, Smits-Engelsman,

Polatajko, & Wilson, 2012). Based on the latest version of the DSM (i.e., DSM-V), four criteria need to be addressed in order to provide a diagnosis of DCD (APA, 2013), including:

A. Acquisition and execution of coordinated motor skills are below what would be expected at a given chronologic age and opportunity for skill learning and use; difficulties are manifested as clumsiness (e.g., dropping or bumping into objects) and as slowness and inaccuracy of performance of motor skills (e.g., catching an object, using scissors, handwriting, riding a bike, or participating in sports).

B. The motor skills deficit significantly or persistently interferes with activities of daily living appropriate to the chronologic age (e.g., self-care and self-maintenance) and impacts academic/school productivity, prevocational and vocational activities, leisure, and play.

C. The onset of symptoms is in the early developmental period.

D. The motor skills deficits cannot be better explained by intellectual disability or visual impairment and are not attributable to a neurologic condition affecting movement (e.g., cerebral palsy, muscular dystrophy, or a degenerative disorder).

A two-step procedure is usually recommended to confirm Criteria A and B using a standardized test of motor coordination (e.g., Movement Assessment Battery for Children – Second Edition or Bruininks-Oseretsky Test of Motor Proficiency – Second Edition) that evaluates children's motor impairments and

parent- or teacher-report questionnaires (e.g., Developmental Coordination Disorder Questionnaire 2007 or Movement Assessment Battery for Children Checklist – Second Edition) that identifies if motor impairments impact children's activities of daily living at home or school (Wright & Sugden, 1996). According to the recommendations provided by the Leeds Consensus Statements, the fifth percentile cut-off on a standardized test should be applied to Criterion A (Sugden, et al., 2006). However, due to the absence of a gold standard for the diagnosis of DCD, the 15th percentile (or 16th percentile using the most edition of the Movement Assessment Battery for Children) is commonly accepted as an appropriate cut-point to identify children with DCD, both for research purposes and early intervention because of concerns regarding misclassifications at lower thresholds (Blank, et al., 2012; Sugden, et al., 2006).

Early onset of symptoms (Criterion C) was introduced into the criteria in the DSM-V. To some extent, this change better reflects the nature of DCD (that it is a "*developmental*" disorder) and differentiates it from some disorders or diseases. On the other hand, it also raises some concerns, such as the difficulty of identifying childhood motor deficits retrospectively when children are assessed in adolescence or early adulthood (Cairney, 2015; Smits-Engelsman, Schoemaker, Delabastita, Hoskens, & Geuze, 2015).

Overall, the current consensus supports the definitions of the DSM-V and the recommendations provided by the Leeds Consensus Statements (Sugden, et al., 2006) and the European Academy of Childhood Disabilities (Blank, et al., 2012).

A flowchart in line with these criteria and practice guidelines was, therefore, proposed to guide the diagnosis of DCD (Smits-Engelsman, et al., 2015, p. 298). However, it is worth noting that even though the DSM-V guides the clinical diagnosis of DCD, not every single criterion can always be thoroughly examined in field-based research, and studies have mainly assessed children's motor performance (Criteria A and B) rather than Criterion C and D. For instance, medical conditions and intellectual functioning are usually reported by parents or observed during the assessment by researchers, rather than through examinations by physicians or pediatricians (Cairney, 2015). Accordingly, the terms *probable*, *possible* and/or *at risk* for DCD are commonly found in the research literature (Smits-Engelsman, et al., 2015). For example, "probable DCD" indicates that all or most of the DSM-V criteria have been evaluated, but some may not have been confirmed (e.g., differential neurological examination to rule out existing disorders that might account for motor impairments). "At risk of DCD" is used to describe preschool children younger than 5 years old who meet the DSM-V criteria, although their motor difficulties have not been repeatedly assessed and confirmed over time (Smits-Engelsman, et al., 2015). Therefore, it is essential to choose the appropriate term in order to improve communication of research findings between researchers and health professionals.

1.1.2 Epidemiology and etiology

According to the DSM-V (APA, 2013), the prevalence of DCD has been estimated to be between 5-6% in 5- to 11-year-old children. However, there is a variation in this number between countries; for example, 13.5% of 7-year-old children were identified as DCD in Sweden (4.9% severe DCD and 8.6% moderate DCD, Kadesjö & Gillberg, 1999), whereas Tsiotra et al. (2006) found that the prevalence was as high as 19% in Greece and 8% in Canada in school-aged children (Tsiotra et al., 2006). A high prevalence of DCD has also been reported in Asia: nearly 18% (7- to 11-year-old) in Japan (Miyahara et al., 1998) and 12% (7- to 10-year-old) in Taiwan (Lin & Wu, 2002). The discrepancy in the rate or prevalence of DCD may be attributed to the use of different cutoff scores on standardized tests (e.g., 5^{th} percentile or 15^{th} percentile) and/or the lack of standardized tests of motor coordination with culturally appropriate referenced norms in some countries (Sugden, et al., 2006). Interestingly, most of the research investigating the prevalence of DCD was conducted before 2006, prior to publication of the Leeds Consensus Statements regarding diagnostic criteria. If a study follows those guidelines, the rates of DCD may be lower, as found by Lingam and colleagues (2009), who used strict diagnostic criteria: scores $\leq 5^{th}$ percentile of a standardized motor test; lowest 10% on a scale of activities of daily living/not meeting national standards for handwriting; absence of reported neurological disease, and an IQ ≥ 70. Using these criteria, a prevalence of 1.8% was reported based on a large cohort of 6867 children (average age 7.5 years) in

the United Kingdom (Lingam, Hunt, Golding, Jongmans, & Emond, 2009). The prevalence of DCD in adults remains unclear mainly because there is no gold standard to assess motor coordination in the adulthood population (Kirby, Edwards, Sugden, & Rosenblum, 2010), and thus far, there is a debate regarding whether children with DCD grow out of motor problems and whether motor impairments track from childhood through adolescence into adulthood (Cantell, Smyth, & Ahonen, 1994; Hands, 2008; Losse et al., 1991; Pless, Carlsson, Sundelin, & Persson, 2002).

DCD has been shown to be more prevalent in boys than girls, with reported sex ratios between 1.8 and five (Kadesjö & Gillberg, 1999; Lingam, et al., 2009; Missiuna, 1994; Zwicker et al., 2013). However, some studies showed no differences in prevalence between sexes (Cairney, Kwan, Hay, & Faught, 2012; Missiuna et al., 2014). This discrepancy may be due to the fact that DCD in boys is often highly comorbid with Attention Deficit/Hyperactivity Disorder (ADHD) (Kadesjö & Gillberg, 1999; Kaplan, Dewey, Crawford, & Wilson, 2001), the latter of which has been found to be more prevalent in boys (Martin, Piek, & Hay, 2006).

The etiology of DCD remains unclear. A systematic review synthesized data from seven studies (four cohort studies and three case-control studies), using the same motor coordination assessment (i.e., Movement Assessment Battery for Children, MABC), and found that school-aged children (5 -18 year-old) with very low birth weight (<1500 g) or very preterm birth (<32 weeks) were more likely to

be diagnosed as severe DCD (odds ratio = 6.29 [4.37 - 9.05]) or moderate DCD (odds ratio = 8.66 [3.40 – 22.07]) (Edwards et al., 2011). These findings are supported by two larger cohort studies (n=7,058 and 32,097, respectively) (Faebo Larsen, Hvas Mortensen, Martinussen, & Nybo Andersen, 2013; Lingam, et al., 2009) and one study that recruited a clinical sample (Zwicker, et al., 2013), indicating that lower birth weight (<2500 g) and younger gestation age at birth (<37 weeks) increased the likelihood of either severe DCD or moderate DCD diagnosed at early years (4- to 7-year-old). Currently, there is a lack of evidence with regard to other prenatal or perinatal risk factors associated with DCD.

Lower birth weight or preterm birth have been linked to increased risk for neurological disorders, neuropsychological and behavioural impairments in children (Nosarti, 2013). As neurological development is compromised in preterm-born children (Nosarti, 2013), the association between DCD and very low birth weight/very preterm birth implies that brain dysfunction may be observed in children with DCD. An increasing number of studies have been conducted to explore the potential causes of DCD. For instance, a systematic review indicated several brain regions as likely candidates that may be affected in children with DCD: cerebellum (motor coordination, motor adaptation, and postural control), parietal lobe (visual-spatial perception and motor imagery), corpus callosum (inter- and intra-sensory modality integration), and basal ganglia (motor control and motor learning) (Zwicker, Missiuna, & Boyd, 2009). Yet, taking into account the deficits of DCD and comorbidity with other disorders (i.e., ADHD or learning

disabilities), the review concluded that cerebellum dysfunction may be primarily responsible for DCD (Zwicker, et al., 2009). However, executive functioning deficits commonly seen in children with DCD (e.g., inhibitory control, working memory, executive attention and affective regulation) (W. Y. Chen, Wilson, & Wu, 2012; Rahimi-Golkhandan, Steenbergen, Piek, & Wilson, 2014; Tal Saban, Ornoy, & Parush, 2014; P. H. Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013), could be also linked to the potential dysfunction in dorsolateral prefrontal cortex or frontal lobe (Brown-Lum & Zwicker, 2015). Considering the complexity of performing daily activities, playing games, and participating in sports, motor coordination and executive/cognitive functions are interconnected (Diamond, 2000). Therefore, a general disorder of brain function, described as *atypical brain development* (Kaplan, et al., 2001), in particular the reciprocal connections between or co-activation of the cerebellum and the frontal/prefrontal cortex (W. Y. Chen, et al., 2012; Diamond, 2000; P. H. Wilson, et al., 2013), may occur in children with DCD (Brown-Lum & Zwicker, 2015). Nevertheless, whether children with DCD experience the difficulty with the co-activation of the cerebellum and prefrontal/frontal areas, or whether cerebellar dysfunction develops prior to dysfunction in the prefrontal/frontal lobe, awaits more evidence to verify.

1.1.3 Clinical features and consequences

The symptoms and signs of DCD and its long-term consequences impact several aspects of childhood well-being. In order to systematically understand the features and consequences of DCD, the model of International Classification of Functioning, Disability and Health (ICF) is employed to organize this section. Specifically, we will focus on the impact of DCD on secondary problems in three domains: (1) body function/structure; (2) activity and participation; and (3) contextual factors (i.e., environmental and personal factors) (WHO, 2007a).

Children with DCD have been found to have a number of neurological soft signs, including hypotonia, abnormal reflexes, and delayed milestones, such as crawling, sitting, or walking (Barnhart, Jo Davenport, Epps, & Nordquist, 2003; Harris, Mickelson, & Zwicker, 2015). Deficits in information processing are also evident in these children. Wilson and colleagues conducted two meta-analyses to explore these deficits based on 50 studies published between 1963 and 1996 and 129 studies published between 1997 and 2011, respectively (P. H. Wilson & McKenzie, 1998; P. H. Wilson, et al., 2013). In the first review, Wilson and McKenzie concluded that children with DCD showed deficits in visual-spatial processing, kinesthetic perception, and cross-modal integration (P. H. Wilson & McKenzie, 1998). In the 2012 review, it was found that children with DCD had deficits in internal modeling, the dynamics of rhythmic coordination, executive functions, postural/gait control, coordination and control of catching and interception, and sensory-perception function (P. H. Wilson, et al., 2013). Taken

together, during the earlier stages of information processing, children with DCD have poor sensory processing abilities or integration (e.g., tactile, proprioception, visual, or verbal/auditory input) (Mon-Williams, Wann, & Pascal, 1999; Zoia, Pelamatti, Cuttini, Casotto, & Scabar, 2002), kinesthetic acuity (Coleman, Piek, & Livesey, 2001), visual-spatial perception with (Schoemaker et al., 2001) or without motor involvement (Hulme, Smart, Moran, & McKinlay, 1984; Tsai, Wilson, & Wu, 2008), and deficits in executive function (i.e. working memory, inhibitory control, attentional shift, and emotion-regulation) (W. Y. Chen, et al., 2012; Rahimi-Golkhandan, et al., 2014; Rigoli, Piek, Kane, & Oosterlaan, 2012a; Tal Saban, et al., 2014). In the later stage of response execution, children, adolescents, and young adults with DCD often show poor sensory-motor integration (de Oliveira & Wann, 2010; Gheysen, Van Waelvelde, & Fias, 2011), and thus, when required to respond to a stimuli or conduct a goal-directed movement, their reaction or movement time is usually longer than typically developing peers (Gheysen, et al., 2011; Tsai, Yu, Chen, & Wu, 2009). They also experience difficulty utilizing motor prediction or feedforward information to adjust their movement or performance (P. H. Wilson, et al., 2013). Furthermore, several studies have indicated that due to the disharmony of agonists and antagonists, or a lack of intra- or inter-limb coordination (Asmussen, Przysucha, & Zerpa, 2014; Raynor, 2001; Rosengren et al., 2009), children with DCD fail to perform smooth, efficient movements, such as one-handed catching (Asmussen, et al., 2014), and have reduced postural stability and increased sway variability,

while walking or when balance is challenged (F. C. Chen et al., 2015; Johnston, Burns, Brauer, & Richardson, 2002; Rosengren, et al., 2009).

Psychosocial functioning, such as self-perception, self-efficacy, and depression/anxiety, is also affected by DCD. Piek and her team have conducted a series of studies investigating perceived domain-specific self-competence and global self-worth in children with DCD (Miyahara & Piek, 2006; Piek, Baynam, & Barrett, 2006; Piek, Dworcan, Barrett, & Coleman, 2000; Rigoli, Piek, & Kane, 2012; Skinner & Piek, 2001), and found consistent evidence showing that DCD (or poor motor skills) is related to lower levels of self-competence, including athletic competence, scholastic competence, and physical appearance (Piek, et al., 2006; Rigoli, Piek, & Kane, 2012; Skinner & Piek, 2001), which may further predict lower global self-worth (Miyahara & Piek, 2006; Piek, et al., 2000). When compared against typically developing children, children with DCD also report significantly lower levels of generalized self-efficacy (Cairney et al., 2005; Cairney et al., 2007).

The impairments mentioned above may further limit children with DCD to appropriately perform self-care, scholastic activities, and participate in daily activities in different settings (Rodger & Mandich, 2005). As the onset of DCD occurs in early childhood, the impact of poor motor coordination may differ between developmental stages. During the preschool age, motor difficulties are most often found to negatively impact self-care activities. A qualitative study interviewed Australian and Canadian parents of 5 to7 year-old children with DCD

regarding their children's skills for dressing, personal hygiene, and eating (Summers, Larkin, & Dewey, 2008). Based on the findings, younger children with DCD failed to show comparative levels of independence to typically developing preschoolers; they had difficulties with the initiation of dressing, buttons, and fastenings of clothing, putting on socks, combing their hair and brushing their teeth in a coordinated manner, wiping their bottoms efficiently, and manipulative skills of using utensils and the maintenance of proper posture while eating meals (Summers, et al., 2008). Furthermore, poor play skills, including object manipulation, reaching or moving, and sequence and organization of objects, were observed in preschool children with DCD (Puderbaugh & Fisher, 1992).

When transitioning to school, many children with DCD grow out of their difficulties with basic or instrumental activities of daily living, in spite of some assistance still needed in a few children (Summers, et al., 2008). Nevertheless, with an increasing demand of motor skills required for scholastic activities (e.g., handwriting, typing, and using scissors) and participation in physical activities and physical education classes (e.g., catching, kicking, dribbling, and any combination of these skills), motor impairments in children with DCD are more easily observed during this developmental period. Poor handwriting skills in school-aged children with DCD usually lead to problems with academic work (Asonitou, Koutsouki, & Charitou, 2010; Gomez et al., 2015; Rigoli, Piek, Kane, & Oosterlaan, 2012b). Moreover, because of the increased time required to tie shoes or button coats/jackets, children with DCD often miss out on recess, which

further reduces time to practice fundamental motor skills and decreases opportunities for social interaction with the peers (Mandich, Polatajko, & Rodger, 2003; Rodger & Mandich, 2005). When considered together, children with DCD may withdraw from and/or participate less in physical activity, and this may eventually lead to poor physical fitness and unhealthy weight status (Cairney & Veldhuizen, 2013; Hendrix, Prins, & Dekkers, 2014; Magalhães, Cardoso, & Missiuna, 2011; Rivilis et al., 2011). Cairney, Faught, and Hay conducted one of the largest prospective studies examining this issue (the Physical Health and Activity Study Team or PHAST project). Enlisting more than 2,200 Grade 4 children in southern Ontario, Canada, Cairney and his team tracked the children's motor coordination, physical activity, and physical fitness, as well as other psychosocial factors (e.g. self-worth, self-efficacy, and internalizing problems) from 2005 to 2009 (J. Cairney, J. Hay, S. Veldhuizen, C. Missiuna, & B. E. Faught, 2010a). The results showed that children with probable DCD (pDCD) consistently spent less time in moderate-to-vigorous physical activity and participated in fewer unorganized (e.g. recreational free play and games) and organized physical activities (e.g. sports teams and physical education lessons) when compared to their coordinated peers (Cairney, Hay, Veldhuizen, et al., 2010a; Kwan, King-Dowling, Hay, Faught, & Cairney, 2016). Children with pDCD were also more likely to be overweight or obese with larger waist circumferences, higher BMI, and a higher percentage of body fat (Cairney et al., 2010; Joshi et al., 2015).

There are limited studies investigating the impact of motor difficulties in young adults with DCD, mostly because of the lack of a gold standard test for the diagnosis (Hands, Licari, & Piek, 2015). Regardless, several studies have shown that motor difficulties and participation limitations (i.e., physical activity and social activities) remain in adults who were previously diagnosed with DCD during childhood or among those who perceived themselves as clumsy as children (Cousins & Smyth, 2003; Hill & Brown, 2013; Kirby, Sugden, Beveridge, & Edwards, 2008). A study found that a majority of 16 to 65 year-old adults with DCD in the United Kingdom reported slowness in reaction and movement time, and continuous deficits in fine motor and gross motor, as well as other relevant functional disabilities, such as reading, riding a bike, and driving (Cousins & Smyth, 2003; Kirby, et al., 2008); social skills, however, seemed to be less of concern in this sample (Kirby, et al., 2008). Furthermore, they were found to be less interested in participating in team games/sports (Kirby, et al., 2008) and spent about 50% less time doing exercise when compared to those without DCD (2 vs. 5 hours/week) (Hill & Brown, 2013).

Finally, in terms of the contextual domain, the impact of the external environment on DCD is also evident. Due to insufficient awareness regarding DCD, children with the condition, not surprisingly, experience less support and more environmental barriers than typically developing children (Mandich, et al., 2003; Rodger & Mandich, 2005). A common situation confronted by parents of children with DCD is the trivialization of the problems due to the poor awareness

among educational and health professionals (Mandich, et al., 2003; Rodger & Mandich, 2005). When parents try to seek professional help, they are usually given the runaround as their children, unlike other children with visible physical disabilities, appear "normal" (Mandich, et al., 2003; Rodger & Mandich, 2005). It is worth noting that, with increasing efforts to improve the public's awareness and transfer knowledge, services and interventions are more accessible for children with DCD today than in the past; for example, it is used to take over 200 days to wait for services for DCD in 2007; wait-times have since decreased to 63 days as of 2009 (Camden, Leger, Morel, & Missiuna, 2015). Nonetheless, a study reported that compared to students with a diagnosis of dyslexia, undergraduate students with DCD were still less likely to be in receipt of support services or funding for any assistive equipment from the government (Kirby, et al., 2008).

1.1.4 Prognosis and treatment

There is a debate regarding the natural progression of DCD. While children with DCD are believed to be able to naturally outgrow motor problems (Cantell, et al., 1994), more evidence seems to support that poor physical fitness, poor academic performance, and behavioural problems may persist in children with DCD from early childhood into adolescence (Hands, 2008; Losse, et al., 1991; Rasmussen & Gillberg, 2000). For instance, in one study, 10- to 12-year-old children who were identified as having low motor competence at the age of 5 to 7 years continued to exhibit poor gross motor and balance, as well as poor

cardiorespiratory fitness (Hands, 2008). Losse and colleagues (1991) also reported that poor motor skills, poor academic achievement, and lower self-perception remained in 15- to 17-year-old clumsy adolescents, all of who were identified 10 years previously as having poor motor coordination, and that approximately 90% of them reported emotional or behavioural problems, such as stealing, poor attendance, lack of self-control, or low self-esteem. In a small sample of young adults with DCD, more than a half of them experienced continuing difficulties with motor skills and executive functions (Kirby, et al., 2008). Furthermore, they were more likely to have additional poor outcomes, including psychiatric disorders, alcohol abuse, or reading/writing disorder (Rasmussen & Gillberg, 2000).

There is some evidence that severity of motor impairment and comorbidity with other disorders in children with DCD impact long-term prognosis. Cantell and colleagues (1994) divided clumsy young children into stable and intermittent groups (based on repeated assessments using the MABC) and followed both groups over a ten-year period. Children in the intermittent group who had delayed motor development at age 5, but not at age 15, still experienced difficulties with motor tasks. However, they were capable of compensating their motor difficulties and succeed in educational performance and social interaction (Cantell, et al., 1994). Similarly, a two-year follow-up study of young children also found that one-third of children at risk for DCD (6^{th} – 15^{th} percentile) identified at the age of 5 to 6 years seemed to grow out of their motor problems two years later,

compared with nearly 80% of children with DCD (at or below the 5th percentile) who continued to show persistent motor coordination difficulties (Pless, et al., 2002).

As DCD is often comorbid with ADHD, children with both disorders may have more profound and persistent problems. In a 22-year longitudinal study, although young adults with ADHD both with and without comorbid DCD diagnosed at 7 years old showed poor prognosis, the ADHD/DCD group had more psychiatric and behavioural problems (e.g. autism spectrum or antisocial personality disorder), as well as fewer years in school at follow-up (Rasmussen & Gillberg, 2000). A few cross-sectional studies have also showed that compared to typically developing or DCD-only children, those with ADHD and DCD were more likely to be more depressed and anxious (Missiuna, et al., 2014; Piek et al., 2007). Therefore, severe motor impairments (at or below the 5th percentile) and comorbidity with ADHD may predispose children with DCD to poor prognosis.

Early interventions can help children with DCD improve their motor skills, develop strategies to overcome difficulties with activities of daily living, and prevent secondary psychosocial implications (Gibbs, Appleton, & Appleton, 2007). Traditional physical and occupational therapies can be generally divided into two methods: task-oriented (top-down) and process-oriented (bottom-up). Task-oriented approaches mainly focus on a child's motor performance on specific tasks or activities in daily living to enhance their participation at home, school, or in the community. Such approaches also focus on motor learning or a

child's problem-solving strategies to facilitate generalization of the skill under practice to other novel tasks which they have not learnt. Cognitive Orientation to Daily Occupational Performance (CO-OP) (Polatajko et al., 2001), neuromotor task training (Niemeijer, Smits-Engelsman, & Schoemaker, 2007), and the Animal Fun program (Piek et al., 2010) are all examples of interventions that use this approach. Conversely, process-oriented approaches focus on fundamental determinants of motor skills by remediating body functions, such as muscle strength and balance, or integrating sensory systems. Sensory Integration (Ayres, 1989) and kinaesthetic training (Laszlo & Sainsbury, 1993) are two examples of bottom-up approaches. A systematic review retrieved 28 studies that conducted a variety of intervention programs in children with DCD between 1970 and 2004 and concluded that both approaches can lead to positive outcomes (Hillier, 2007). Nevertheless, two recent reviews indicated that the effects for process-oriented approaches were weak (weighted Cohen's $d = 0.12$) and had little effects on the improvement in occupational performance in children with DCD (Armstrong, 2012; Smits-Engelsman et al., 2013). Instead, task-oriented approaches (weighted Cohen's $d = 0.89$) and perceptual-motor-based interventions (weighted Cohen's $d = 0.83$) yielded stronger effects to improve the DCD children's motor performance, participation in daily activities or physical activity at home or school, and cognitive abilities (Smits-Engelsman, et al., 2013). Other alternative interventions, such as exercise intervention (Tsai, 2009) and music therapy (Leemrijse, Meijer, Vermeer, Ader, & Diemel, 2000), also have promising effects

on executive function (e.g., inhibitory control/attentional shifting) and motor performance (e.g., gross/fine motor skills and rhythmic movements) in children with DCD. However, as DCD is a heterogeneous group, health professionals and therapists should bear in mind that there is likely not a single approach which will be suitable for all children with DCD (Hillier, 2007; Smits-Engelsman, et al., 2013). The choice of the interventions has to be based on the holistic evaluation, and the setting of the goals should be child-centered. More importantly, the involvement of parents and school teachers would not only provide additional support but also sustain the treatment effects (Camden, et al., 2015; Smits-Engelsman, et al., 2013; Sugden & Chambers, 2003).

1.2 INTERNALIZING PROBLEMS

1.2.1 Definitions, prevalence, and causes

Child and adolescent psychiatric symptoms are generally grouped into two, broad categories: internalizing and externalizing problems (Achenbach, 1966). While externalizing problems refer to harmful and disruptive behaviours (e.g., aggressiveness or rule-breaking behaviours), internalizing problems are inner-directed, affecting emotions and moods causing unease, tension, and suffering in the individual (Forns, Abad, & Kirchner, 2011; Zahn-Waxler, Klimes-Dougan, & Slattery, 2000). The first appearance of the term internalizing problems can be traced back to a study conducted by Achenbach in 1966, in which factor analysis was used to categorize child and adolescence psychopathology and showed that

internalizing problems were one of two broad-band syndromes. In addition, their further research identified four narrower-band syndromes related to internalizing problems: anxious-depressed, schizoid, somatic complaints, and withdrawn (Ollendick & King, 1994). This is very similar to the current framework used in the DSM-V, indicating that internalizing problems represent disorders with prominent anxiety (e.g., separation anxiety disorder and generalized anxiety disorder), depression (e.g., major depressive disorder), and somatic symptoms (e.g., somatization disorder), as well as other affective or emotional disorders, such as phobia, panic, and obsessive-compulsive disorder (APA, 2013). As internalizing problems are subjective, inner states, they are often more difficult to detect in children, particularly very young children, than externalizing problems that are overt behaviours which may easily be observed by parents or teachers (Forns, et al., 2011).

In this dissertation, internalizing problems, which was reported by parents on the Child Behavior Checklist in young children (Achenbach & Rescorla, 2000) and self-reported on the K6 scale in school-aged children and young adults (Kessler et al., 2002), are defined as general symptoms of psychological distress, which include negative affect (sadness), anxiety, negative emotional reaction, and social withdrawal. In young children, somatic complaints are also considered as part of internalizing symptoms.

Internalizing problems, especially anxiety and depression, are the most frequent mental health problems in children and adolescents with a lifetime

prevalence of up to 30% (Kessler, Petukhova, Sampson, Zaslavsky, & Wittchen, 2012). According to several national surveys in North America, the lifetime prevalence of any anxiety and depressive disorder in 4 to 17 year-old children and adolescents is estimated about 6% and 4%, respectively (Boyle & Georgiades, 2010). Both are higher than those of other childhood neurological diseases or physical disabilities, such as cerebral palsy (1.5 to 4 per 1,000 live births), muscular dystrophy (1.3 to 1.8 per 10,000 males), or spinal bifida (2.7 to 3.8 per 10,000 per live births) (Centers for Disease Control and Prevention, 2016). Importantly, when the age group is confined to 13 to 17 year-olds only, the lifetime prevalence increases significantly to 32.4% for any anxiety disorder and 14.4% for any depressive disorder (Kessler, et al., 2012). The prevalence remains similar in adults aged between 18 to 64 years for any anxiety disorder (33.7%) and slightly increases for any depressive disorder (21.4%).

The causes of internalizing problems are multi-dimensional. Based on the existing evidence, there may not be a single cause or etiology that could fully account for the onset of internalizing problems. Twins studies, for example, indicated that approximately 30-40% of the variance in general anxiety disorders and 50% of the variance in mood disorders could be genetically explained, and that non-shared environmental factors, rather than shared adverse environmental risks, accounted for the remaining variance (Beesdo, Knappe, & Pine, 2009; Lima et al., 2013; Parker & Roy, 2001). With regard to specific biological mechanisms, research is on-going. Using neuroimaging techniques, there is emerging evidence

that the etiology of childhood major depressive disorders may be linked to the corticolimbic functional connectivity alterations in limbic and dorsal frontal/parietal regions, showing a reduced connectivity within networks related to the amygdala, which would impact the emotional regulation (Lima, et al., 2013). Moreover, internalizing problems, particularly depression, has been linked to increased activity of the hypothalamic-pituitary-adrenal axis with hypercortisolemia (i.e., permanently higher serum levels of cortisol), impaired inhibitory feedback of the hypothalamic-pituitary-adrenal axis by circulating glucocorticoids, and dysfunction of glucocorticoid receptors at hypothalamus and pituitary (Tofoli, Baes, Martins, & Juruena, 2011; Tsigos & Chrousos, 2002). Nevertheless, the evidence is still preliminary, and more neuroimaging studies are needed to increase our understanding of the underlying etiology and mechanisms regarding brain dysfunction from a neuro-physiological perspective.

1.2.2 Risk factors

Depression and anxiety, two major components of internalizing problems, have been extensively studied in epidemiological studies over the past few decades (Tandon, Cardeli, & Luby, 2009), and have been found to be highly comorbid with each other across time due to phenomenological similarities (Cummings, Caporino, & Kendall, 2014). In a nationally representative cohort of Canadian children at ages of 4 to 7 years, anxiety and depression were significantly highly correlated across time (r = .49 at age 4-6 in 1994, r = .60 at

age 8-10 in 1998, and r = .59 at age 12-14 in 2002) (Boylan, Miller, Vaillancourt, & Szatmari, 2011). Therefore, this dissertation includes these two symptoms as shared outcomes of interest, and in this section, possible common risk factors for both conditions are reviewed. Furthermore, it is worth noting that risk factors or predictors of internalizing problems varies across the life course (WHO, 2014). Given that the early onset of internalizing problems may become chronic and cause long-term negative consequences in health and well-being, and that the prevalence of these disorders steeply increases at school age (Kessler, et al., 2012), it is essential to specifically identify risk factors of internalizing problems in childhood and adolescence in order to design and implement appropriate interventions. Therefore, this section reviews those salient risk factors of childhood and adolescent internalizing problems from three different domains, including individual, parental, and family.

Evidence was synthesized from several systematic reviews and meta-analysis studies to identify more salient factors that predict childhood and adolescent anxiety and depression. At the individual level, gender or sex is a strong predictor for both anxiety and depression (Asselmann & Beesdo-Baum, 2015; Beesdo, et al., 2009; Weeks et al., 2014). The effect of gender/sex is considered less critical in childhood; however, the difference in the prevalence between boys and girls increases with age and emerges when transitioning into adolescence at the ages of around 15 years: during this time, female adolescents are almost twice as likely as male adolescents to develop anxiety or depression

(Beesdo, et al., 2009; Cairney, 1998; Petersen et al., 1993; Wade, Cairney, & Pevalin, 2002). The underlying reasons for higher odds of being depressed or anxious in girls remains unclear, but may be related to earlier biological changes of puberty and poor coping with peer and relationship stress (Petersen, et al., 1993; Weeks, et al., 2014).

Another important risk factor at the individual level is temperament or personality trait (Asselmann & Beesdo-Baum, 2015; Beesdo, et al., 2009; Hirshfeld-Becker, Micco, Simoes, & Henin, 2008; Parker & Roy, 2001; Weeks, et al., 2014). Consistently, difficult temperament and negative personality traits, including shyness, elevated anxiety sensitivity, dependence, behavioural inhibition (i.e., being withdrawn when faced with strangers or unfamiliar situations), or neuroticism, have been found to predispose children and adolescents to greater risk for internalizing problems (Asselmann & Beesdo-Baum, 2015; Beesdo, et al., 2009; Hirshfeld-Becker, et al., 2008; Parker & Roy, 2001). These risk factors may further lead to the development of negative psychological coping resources, such as low self-esteem or self-worth, self-criticism, low mastery, low life satisfaction, and a lack of control over negative life events, which have been also linked to increased depressed and anxious symptoms (Asselmann & Beesdo-Baum, 2015; Parker & Roy, 2001). Difficult temperament was also found to be associated with the severity of internalizing problems by a previous longitudinal analysis using the Canadian National Longitudinal Survey of Children and Youth, indicating that it significantly and

consistently predicted moderate (odds ratio = 2.42, 95%CI [1.71, 3.43]) and high levels (odds ratio = 1.76, 95%CI [1.38, 2.24]) of symptoms of internalizing problems, when compared against a reference group with consistently low levels of symptoms (Weeks, et al., 2014).

Other early childhood adversities, such as physical/psychological/sexual abuse, physical or emotional neglect, or domestic violence (Asselmann & Beesdo-Baum, 2015; Beesdo, et al., 2009; Lima, et al., 2013; WHO, 2014), are not only directly related to internalizing problems in childhood and early adolescence, but also have an indirect effect (through childhood internalizing problems) on brain structure in later adolescence and early adulthood (18-21 years), *for instance* lower thickness of superior frontal gyrus volume (Jensen et al., 2015).

In order to identify early and intervene appropriately, parents play a crucial role with regards to internalizing problems in children and adolescents. A number of modifiable parental factors have been found to predict childhood and adolescent anxious and depressive symptoms (Yap & Jorm, 2015). Parental, specifically maternal mental illness is one of the strongest risk factors (Beesdo, et al., 2009; Bogels & Brechman-Toussaint, 2006; Parker & Roy, 2001; WHO, 2014). Both prenatal and postnatal maternal anxiety and depression increase the risk for anxiety and depression in children (Parker & Roy, 2001; WHO, 2014). For example, compared to the reference group, the odds of showing early childhood onset of internalizing problems (odds ratio = 2.15) or relatively stable, high levels of symptoms from early childhood to adolescence (odds ratio = 1.65 –

2.18) have been found to be significantly higher in the presence of maternal depression (Weeks, et al., 2014). The cause of the overlap between parental and childhood anxiety and/or depression remains uncertain (Bogels & Brechman-Toussaint, 2006). Genetic transmission may predispose children to be inherently more vulnerable to internalizing problems, whereas family factors, such as parent-child attachment, family functions, or parenting styles, could also play a role (Bogels & Brechman-Toussaint, 2006). Three parental behaviours found to impact internalizing problems in children have been widely investigated: parenting types, parental drug/alcohol use, and inter-parental conflict (Asselmann & Beesdo-Baum, 2015; Beesdo, et al., 2009; Bogels & Brechman-Toussaint, 2006; Hirshfeld-Becker, et al., 2008; Lima, et al., 2013; WHO, 2014; Yap & Jorm, 2015).

A meta-analysis of 50 studies (13 longitudinal, 26%) examined the effects of parenting styles (i.e., rejection and control) on anxiety, depression, and internalizing symptoms in 5 to 11 year-old children (Yap & Jorm, 2015). The results showed that the "rejection" type of aversiveness and warmth, and the "control" type of over-involvement, were consistently and significantly predictive of childhood anxiety (over-involvement: $r = 0.254$), depression (aversiveness: $r = 0.287 – 0.327$; warmth: $r = -0.172$; over-involvement: $r = 0.230$), and internalizing symptoms (aversiveness: $r = 0.171 – 0.173$; warmth: $r = -0.172$; over-involvement: $r = 0.133 – 0.242$). In general, parents of anxious or depressed children are likely to be more over-controlling, less warm, and less accepting,

which may result in poor emotional regulation and low self-efficacy in their children (Hirshfeld-Becker, et al., 2008). As for parental behavioural problems, prenatal alcohol and drug use is considered to interfere with the child's emotion regulation and subsequently result in the early onset of childhood internalizing problems (Lima, et al., 2013; WHO, 2014). Finally, emerging evidence supports the deleterious effect of interparental conflict on children's mental health (Lima, et al., 2013; WHO, 2014; Yap & Jorm, 2015). However, as only small (but statistically significant) effect sizes were found for anxiety (effect size = 0.155), depression (effect size = 0.161 – 0.169), and both symptoms (effect size = 0.170 – 0.187), inter-parental conflict may only exert an indirect effect through other factors (e.g., negative parenting styles or emotional security) (Yap & Jorm, 2015).

Several family or environmental risk factors have been shown to be associated with childhood or adolescent internalizing problems (Asselmann & Beesdo-Baum, 2015; Beesdo, et al., 2009; Bogels & Brechman-Toussaint, 2006; Hirshfeld-Becker, et al., 2008; Lemstra et al., 2008; WHO, 2014), of which the most consistent predictor is low socioeconomic status, especially low income or poverty (Beesdo, et al., 2009; Lemstra, et al., 2008; WHO, 2014). An inverse association between socioeconomic status and internalizing problems has been found in 10 to 15 year-old children by a systematic review synthesizing findings from nine studies (seven of which used income as the single indicator of socioeconomic status), indicating that the prevalence of depression and anxiety is approximately 2.5 times higher in children from families of low socioeconomic

status than those from higher socioeconomic status (Lemstra, et al., 2008). Poverty exposes family members, including both parents and children, to stressful and difficult home environments which could further induce parental and childhood mental illness and predict the recurrence episodes (Beesdo, et al., 2009; Lemstra, et al., 2008; Parker & Roy, 2001). In addition, family structure and functioning are contributing factors to childhood and adolescent internalizing problems. Fragile family structure (e.g., parental separation, divorce, and larger family size) and family dysfunction (e.g. lack of family adaptability, poor family communication or interaction, and poor marital quality) are associated with elevated risk for childhood and adolescent internalizing problems (Asselmann & Beesdo-Baum, 2015; Bogels & Brechman-Toussaint, 2006; Hirshfeld-Becker, et al., 2008; Parker & Roy, 2001).

Taking into account the early onset and persistent severity of internalizing symptoms on future treatment response (Nilsen, Eisemann, & Kvernmo, 2013), early identification of risk factors is extremely important to prevent internalizing problems, and reduce the persistence and recurrence of these problems later in life. Nevertheless, to date, there has been no study which has examined multiple correlates or determinants of internalizing problems in children with DCD. Compared to the general population, our understanding of risk factors predicting internalizing problems in the DCD population is much more limited. This issue awaits more research to be investigated from both cross-sectional and longitudinal perspectives.

1.2.3 Internalizing problems and Developmental Coordination Disorder

Compared to other areas of research on the DCD population, such as etiology, motor learning and control, or physical health, a relatively smaller number of studies (approximately 20 papers specifically focusing on the DCD or poor motor coordination population) has been conducted to investigate associations between motor coordination problems and internalizing problems, particularly depression and anxiety, since the first paper was published to highlight this issue in this population (Losse, et al., 1991).

Since that paper, a number of studies have confirmed elevated internalizing problems in children and adolescents with DCD. Despite a diversity of measures used by researchers (e.g., Child Behavior Checklist, State-Trait Anxiety Inventory, Self-report for Childhood Anxiety and Related Emotional Disorders, and The Spence Children's Anxiety Scale), school-aged children with clumsiness or DCD aged between 6 and 14 years have been consistently reported to be at greater risk for anxiety (Missiuna, et al., 2014; Pratt & Hill, 2011; Schoemaker & Kalverboer, 1994; Skinner & Piek, 2001). Furthermore, the parent-reported prevalence for clinical anxiety is remarkably higher in children with DCD (16.7%, 11 out of 68) when compared against unaffected children (1.1%, 1 out of 91) (Missiuna, et al., 2014). Depression levels were also found to be higher in school-aged children with DCD (Lingam et al., 2012; Missiuna, et al., 2014), with the proportion of children reporting depressive symptoms being almost double in the DCD group compared to the typically developing children

(11.9% vs. 5.3%, OR=2.41) (Lingam, et al., 2012). Furthermore, two studies enrolling community adolescent samples (327 Finnish girls and 93 Australian children at the ages between 12 and 16 years) with a wider spectrum of motor coordination found significant weak to moderate associations between motor skills (especially gross motor) and psychosocial well-being (-0.24 to -0.30 for depression; -0.30 to -0.32 for anxiety), indicating that adolescents with poor motor skills may be at greater risk for internalizing problems (Rigoli, Piek, & Kane, 2012; Viholainen, Aro, Purtsi, Tolvanen, & Cantell, 2014).

Interestingly, in contrast with the consistent findings in the school-aged population, the findings are mixed in preschool children. Both Pike, et al. (2008) and King-Dowling, et al. (2015) used the same measure, the Child Behavior Checklist, to evaluate internalizing problems (i.e., emotionally reactive, anxious/depressed, somatic complaints, and withdrawn) in young children (3- to 6-year-old) (King-Dowling, Missiuna, Rodriguez, Greenway, & Cairney, 2015; Piek, Bradbury, Elsley, & Tate, 2008), and found contradictory results: while Australian preschool children at risk for DCD reported significantly more internalizing problems than those without DCD, this group difference was not identified in Canadian preschool children. Due to limited evidence, we do not exactly know if the discrepancy between two studies could be simply attributed to cross-cultural or other between country differences, or if it could be biased by small sample sizes in both studies: only 14 DCD in Piek's study and 37 in King-

Dowling's. More research is needed to clarify the relationship between DCD (or poor motor coordination) and internalizing problems in young children.

The underlying mechanisms connecting DCD to internalizing problems has not been clear to date. Considering that DCD and anxious/depressive behaviours may occur together from early childhood (Piek, et al., 2008; A. Wilson, Piek, & Kane, 2013), both problems may be linked genetically, or share similar etiology (Piek, et al., 2008). The results from a twin study with a total of 398 pairs (144 monozygotic and 254 dizygotic) aged 8-17 years in Italy confirmed this assumption by showing that the cross-twin/within-trait correlations were greater in monozygotic pairs than in dizygotic ones (coefficients: 0.46 vs. 0.21 for clumsiness, and 0.53 vs. 0.30 for anxiety), and that the best fit was found in the model where the covariance between clumsiness and anxiety was interpreted only by genetic factors, rather than shared and non-shared environmental factors or any of their combinations (Moruzzi et al., 2010). Nevertheless, there is also evidence indicating that non-shared environmental factors seem to be the most important contributor to the co-existence of DCD and internalizing problems. Three other twin studies have found that children and adults with DCD or motor disorders have significantly greater levels of anxious and depressive symptoms than their co-twin without the disorder, highlighting the indispensable role of unique (non-shared) environmental effects on the etiology of internalizing problems in those with motor impairments (Pearsall-Jones, Piek, Rigoli, Martin, & Levy, 2011; Piek, et al., 2007; Waszczuk, Leonard, Hill, Rowe, & Gregory, 2016). Taken together,

according to the existing evidence from the co-twin studies, both genetic and non-shared environmental influences are likely part of the etiological mechanisms linking DCD to internalizing problems.

It is worth noting that the importance of non-shared environmental factors suggests the ESH (Cairney, Rigoli, & Piek, 2013) may be an appropriate framework to enhance our horizon regarding the underlying mechanisms of internalizing problems in children with DCD. As noted by Piek's study (2007), increased internalizing problems confronted by children with DCD may be due to their unique and specific contextual experiences, such as poor social relationships and social support, or negative self-concept (Piek, et al., 2007), all of which compose important parts of the ESH and mediate and/or moderate the relationship between DCD and internalizing problems. Perhaps as importantly, the ESH identifies modifiable risk and protective factors, that if truly linked to internalizing problems in children with DCD, could serve as effective targets for intervention. Genetic factors, while important, are less amenable to intervention generally speaking. The more details with respect to the underlying pathways of the ESH are described in the following section.

1.3 ENVIRONMENTAL STRESS HYPOTHESIS

The ESH (Cairney, et al., 2013) guides the research objectives of this dissertation. The following sections will first introduce Pearlin's Stress Process model, which is the core of the ESH, and then describe the development of the ESH in greater detail, including its context, applications, and potential limitations.

1.3.1 Stress Process model

Pearlin's Stress Process model consists of three major components: stressors, stress mediators, and stress outcomes (Pearlin, 1989). Stress is defined as "*any environmental, social, or internal demand which requires the individual to readjust his/her usual behavior patterns* (Holmes & Rahe, 1967)". This model illustrates how stress or stressors affect an individual's self-concept, coping strategies, and social support, and how these primary (e.g., job disruption) and secondary (e.g., economic strain change) stressors form together to pose a deleterious effect on mental health and evoke psychological distress (Pearlin, Menaghan, Lieberman, & Mullan, 1981). The stressors include stressful life events (e.g., disruption of work life or marriage) that are "*acute changes which require major behavioural readjustments within a relatively short period of time* " and chronic strains (e.g., poverty or long-term poor social relationship) that refer to "*persistent or recurrent demands which require readjustments over prolonged period of time*" and may cause interpersonal conflicts, inter-role conflicts, or role restructuring (Pearlin, 1989; Thoits, 1995). According to Pearlin, it is important to

separate stress from distress, as often the two terms are used interchangeably. Stress refers to contextual or intrinsic demands causing behavioural or emotional changes that are not necessarily harmful, whereas distress is defined as "*an aversive, negative state in which coping and adaptation processes fail to return an organism to physiological and/or psychological homeostasis*" (Moberg, 1987). Specifically, psychological distress (e.g., feeling hopeless or depressed/anxious, feeling worthless, or being so nervous) refers to "*the unique discomforting, emotional state*" in response to stressors or demands that interfere with functioning in daily living (Ridner, 2004).

In Pearlin's classic longitudinal study (1981), he and his research team found that stress, specifically job disruption, eroded positive self-concept (i.e., mastery and self-esteem), which in turn resulted in depression (Pearlin, 1989; Pearlin, et al., 1981). Furthermore, coping strategies and social support, both of which may modify the situation of stress, mediated and buffered the adverse effect of stress on mental health (Pearlin, 1989; Pearlin, et al., 1981). Ultimately, the accumulation of unsolved stressors further deteriorates mental health (Thoits, 1995; Turner, Wheaton, & Lloyd, 1995). Therefore, Pearlin's Stress Process model includes two important hypotheses: stress erosion hypothesis (mediation) and the buffering model (moderation) (Cairney, et al., 2013). In terms of the erosion process, exposure to stress or chronic stressful events increases psychological distress, analogous to internalizing problems, through the direct or indirect effect of loss of social support and stress-related negative changes in self-

concept. On the other hand, social support and positive self-concept can protect (or buffer) the negative impact of stress on mental health (Bovier, Chamot, & Perneger, 2004; Pearlin, 1989; Pearlin, et al., 1981; Thoits, 1995; Turner, et al., 1995).

A major strength of Pearlin's Stress Process model is its flexibility for research to identify specific stressors and mediators, as well as the outcomes of mental health, according to their research interests and questions (Cairney, et al., 2013). As a result, Pearlin's Stress Process model remains widely utilized to enhance our understanding of the effect of a variety of stressors on mental health problems in different populations (Gilster, 2014; Kim & Chung, 2016), and assist policy-making (Alang, McAlpine, & Henning-Smith, 2014). It is indeed for this reason that Pearlin's Stress Process model was selected by Cairney and colleagues as a starting point to develop the ESH by including DCD, physical inactivity, and obesity as the preceding stressors of the stress process leading to internalizing problems (Cairney, et al., 2013).

1.3.2 Environmental Stress Hypothesis

The ESH was first proposed by Cairney and colleagues to identify possible mechanisms leading to greater internalizing problems in children with DCD (Cairney, Veldhuizen, & Szatmari, 2010). It is hypothesized that "*coordination problems act as a primary stressor, children are exposed to a cascade of negative psychosocial consequences (secondary stressors), which in turn lead to negative*

appraisals of self and to increased symptoms of depression and anxiety." This conceptual framework remained unclear and undeveloped until a recent comprehensive treatment of the ESH was provided, including a model specifically outlining potential pathways between DCD and internalizing problems (Cairney, et al., 2013).

As highlighted by Thoits (1995), it is not only important to understand the consequences of stressors, but the sequences leading to their development. The ESH is a complex model illustrating the sequential, underlying mechanisms of internalizing problems in children with DCD (*see* Figure 1). In this model, DCD is positioned as a primary stressor that initiates a cascade of adverse effects on physical (i.e., physical activity and healthy weight status), psychosocial (i.e., interpersonal relationships, social and personal resources), and mental well-being (specifically internalizing problems) (Cairney, et al., 2013). Furthermore, physical inactivity and overweight or obesity that arise as the consequences of DCD can deplete a child's psychosocial resources, including interpersonal conflicts, social (i.e., perceived social support) and personal (i.e., self-concept) resources.

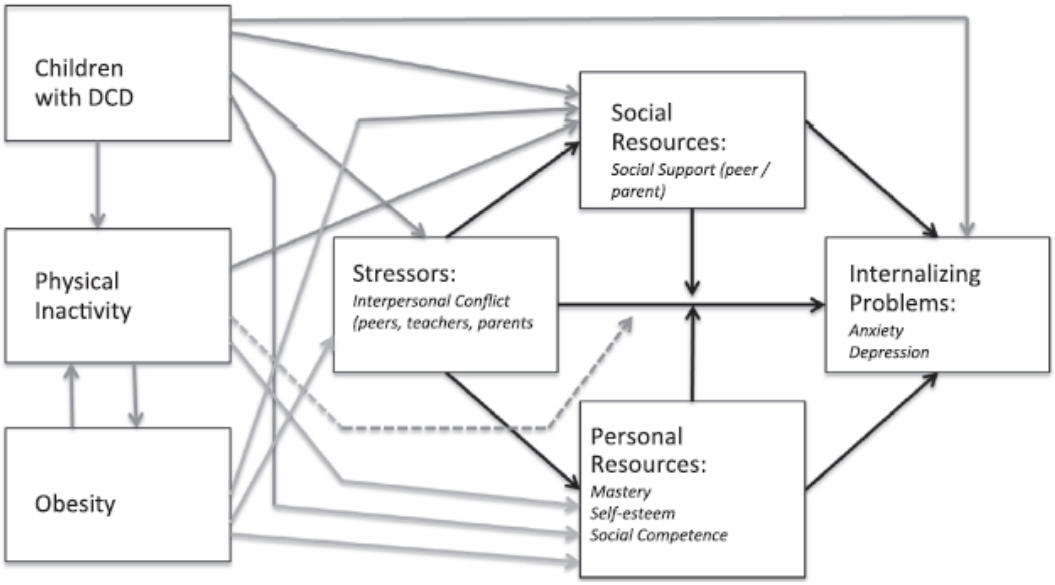

Figure 1. The conceptual framework of the ESH. Reprinted from "Developmental coordination disorder and internalizing problems in children: The environmental stress hypothesis elaborated," by J. Cairney, et al., 2013, *Developmental Review, 33,* p. 233. Reprinted with permission.

As DCD is a chronic, persistent health issue with onset occurring in early childhood (APA, 2013), positioning the disorder as a primary stressor having a direct effect on physical health and psychosocial well-being in the ESH seems justified (Cairney, et al., 2013). The ESH is a novel and unique model as it identifies specific mediating and moderating pathways linking DCD to internalizing problems. The mediating pathways in the ESH suggest that DCD leads to physical inactivity and obesity, resulting in greater interpersonal conflicts that negatively impact their perceptions of social support and self-concept, including self-esteem, mastery, and self-competence; consequently, children with DCD exposed to these secondary stressors are more likely to experience internalizing problems through these mediating variables, including physical

inactivity, obesity, interpersonal conflicts, lower perceived social support, and negative self-concept (Cairney, et al., 2013).

Although there remains limited direct evidence supporting all pathways hypothesized in the ESH, there is sufficient indirect evidence supporting the (partial) mediating pathways in children with DCD, as well as community based samples (Lingam, et al., 2012; Mancini, Rigoli, Heritage, Roberts, & Piek, 2016; Rigoli, Piek, & Kane, 2012; Viholainen, et al., 2014; A. Wilson, et al., 2013). A recent mini-review of this model highlights that the most rigorous evidence supports the mediating effect of self-concept on the relationship between DCD or poor motor coordination and internalizing problems in children or adolescents (Mancini, Rigoli, Cairney, Roberts, & Piek, 2016). In larger community samples (n=6,902 in the UK, n=327 in the Netherlands, and n=93 in Australia), poor motor coordination has been found to have a stable indirect effect on internalizing problems through personal resources, including self-esteem/global self-worth (Lingam, et al., 2012; Rigoli, Piek, & Kane, 2012) and domain-specific self-perceptions (e.g., physical ability, physical appearance, and academic achievement) (Rigoli, Piek, & Kane, 2012; Viholainen, et al., 2014). A relatively small number of studies have investigated the mediation of interpersonal conflicts and perceived social support on the relationship between DCD and internalizing problems (Lingam, et al., 2012; Mancini, Rigoli, Heritage, et al., 2016; Skinner & Piek, 2001; Viholainen, et al., 2014). However, existing evidence does support the conceptual pathways of the ESH, demonstrating that internalizing problems in

children with DCD is mediated by social skills and peer victimization, both of which could be referred as the measures of interpersonal conflicts (Lingam, et al., 2012; Viholainen, et al., 2014). Children with DCD or poor motor coordination have poor social skills (e.g., communication, cooperation, and self-control behaviours) and poor social relationships (e.g., being bullied and difficulties making friendships); consequently, children with poor motor coordination appear to have increased depressive and anxious symptoms (Lingam, et al., 2012; Viholainen, et al., 2014). Furthermore, there is some evidence that perceived social support may mediate the relationship between poor motor coordination and internalizing problems in adolescents (Mancini, Rigoli, Heritage, et al., 2016). Nevertheless, the mediation of perceived social support appears to be true only for source of family support, not friends or significant others, and this mediating effect may only exist for depression, not for anxiety (Mancini, Rigoli, Heritage, et al., 2016). As evidence regarding the mediation of perceived social support could be only obtained from one study, these findings must be interpreted with caution. Further investigations are needed to replicate these findings and to determine whether perceived social support also mediates the effect of DCD on internalizing problems across the lifespan as DCD is a life-long health concern.

The ESH also includes three moderating pathways, which provide the buffering effects of physical activity, and the positive perceptions of social support and self-concept on the relationship between DCD and internalizing problems (Cairney, et al., 2013). While no study has tested these moderating

pathways directly to date, existing intervention studies may provide insight into these relationships. For example, a six-month intervention of the Animal Fun program has been shown to benefit preschool children's motor skills and emotional and behavioural problems by engaging in specially designed physical movements (e.g., locomotion, object control, body sequencing, fine motor and hands skills) in a positive, social play environment (Piek et al., 2015; Piek et al., 2013). Furthermore, this intervention effect was sustained over 12 months when these children transitioned into Grade 1. Therefore, there is potential of increasing perceptions of social support and self-concept in children with DCD through participation in physical activity, which can further buffer the adverse effect of DCD on mental health.

1.3.3 Limitations

The ESH provides a comprehensive theoretical framework guiding the future research directions that would enhance our understanding toward the underlying mechanisms of internalizing problems in children with DCD, and informing the interventions integrating physical and psychosocial health to prevent or improve internalizing problems. However, we should recognize that the ESH is a new framework and still under development. Many of its potential pathways have not been examined, there are a few limitations that need to be addressed.

Frist, as noted by Cairney and colleagues (2013) in their original review, "*while there is a plausible link from inactivity to obesity to increase risk of internalizing problems in children with DCD, we know of no research that has examined these associations directly*" (p. 234). As children with DCD are more likely to be physically inactive and overweight/obese, two direct paths from physical activity and obesity to internalizing problems should be incorporated in the ESH to highlight their potential mediating effects on the relationship between DCD and internalizing problems, in addition to the sequential mediating effects of physical activity through psychosocial resources and obesity through interpersonal conflicts and psychosocial resources on this relationship. A large body of literature has demonstrated the direct effects of physical activity and obesity on mental illness (Biddle & Asare, 2011; Hoare, Skouteris, Fuller-Tyszkiewicz, Millar, & Allender, 2014). While evidence remains limited, physical activity and exercise are believed to have both antidepressant and anxiolytic effects (Pedersen & Saltin, 2015). A large population-based study conducted in the Netherlands has shown that regular exercisers (at least 60 min/week at the intensity of 4 METs) are less anxious and depressed compared to non-regular exercisers (De Moor, Beem, Stubbe, Boomsma, & De Geus, 2006). Therefore, participating in physical activity can develop and improve emotion control, social relations with the peers, and physiological responses, such as releasing norepinephrine and endogenous opioid in the brain (Lawlor & Hopker, 2001;

Salmon, 2001). Consequently, these physiological and psychosocial benefits may be able to foster mental health.

Obesity and its risk factors (e.g., physical inactivity and unhealthy diet) are also strongly linked to mental health problems, specifically depression (Hoare, et al., 2014). A systematic review conducted by Hoare and colleagues (2014) found that obesity status in adolescence significantly predicted depressive symptoms in adulthood, and that the association was stronger in females (Hoare, et al., 2014). A community-based intervention identified a positive effect of a 9-week obesity prevention program on anxiety ($d=-0.56$, $p<.05$) in children and adolescents (Melnyk et al., 2009). As obesity is a chronic inflammation condition, evidence has shown that it leads to the release of cytokines (e.g. Tumor Necrosis Factor-α or Interluekin-6) that appear to negatively impact body immune system and cause dysregulation of the hypothalamic-pituitary-adrenal axis, both of which have been linked to internalizing problems (Felger & Lotrich, 2013; Hosick et al., 2013; Tsigosa & Chrousos, 2002).

Second, child development is a dynamic process, which implies that the underlying mechanisms of internalizing problems in the DCD population may change over time and may differ between the sexes. There are several longitudinal studies in children with DCD that demonstrate interaction effects, which may affirm the hypothesized importance of time and sex effects on the underlying mechanisms of internalizing problems (Cairney, Hay, Veldhuizen, Missiuna, Mahlberg, et al., 2010; J. Cairney, J. A. Hay, S. Veldhuizen, C. Missiuna, & B. E.

Faught, 2010b; Joshi, et al., 2015; Kwan, et al., 2016). For example, the pattern of change in physical activity over time in children with DCD appears to differ by sex; specifically, the activity deficit diminishes over time in boys, but remains unchanged or increases in girls (Cairney, Hay, Veldhuizen, et al., 2010b). Therefore, if physical inactivity is indeed a risk factor for internalizing problems, the effect may be more pronounced for girls given their sustained activity-deficit over time. Similarly, children with DCD demonstrate a persistently greater prevalence of overweight and obesity (e.g., higher BMI or larger waist circumference) over approximately five years (Cairney, Hay, Veldhuizen, Missiuna, Mahlberg, et al., 2010; Joshi, et al., 2015); however, the gaps in BMI and waist circumference between children with and without DCD differ by sex, indicating that the gaps only enlarge in boys over time (Joshi, et al., 2015). Accordingly, as BMI and waist circumference are two important indices of obesity, which is one of stressors leading to internalizing problems in children with DCD (Cairney, et al., 2013), a stronger long-term effect of BMI or waist circumference may be expected on internalizing problems in boys with DCD than girls with this disorder. These longitudinal findings highlight the need of the investigation of the ESH from a developmental perspective, and we must examine these underlying pathways at different ages, such as early, middle, and late childhood.

Furthermore, longitudinal studies have shown that the early onset of motor impairments or poor motor skills that precede the development of internalizing

problems predicts increased symptoms of depression and anxiety later in life (Mancini, Rigoli, Cairney, et al., 2016). For example, greater variation in gross, but not fine, motor performance from four months to four years predicted more depressive and anxious problems at school age of 6-12 years (Piek, Barrett, Smith, Rigoli, & Gasson, 2010). Observed (e.g., delayed walking or poor hand control) or self-reported (e.g., the frequency of having difficulties with team sports, self-care activities, or riding a bike) childhood motor difficulties at school ages also predicted increased maternal- or self-reported symptoms of depression and anxiety in adolescence (i.e., 16 years old) and adulthood (i.e., 22 to 33 years old) (Poole et al., 2015; Sigurdsson, Van Os, & Fombonne, 2002). Nevertheless, to the best of our knowledge, only one study that examined the relationship between motor coordination and internalizing problems in a sample of 40 children aged 3 to 5 years (14 at risk of DCD) found a significant negative association (r=-.40, p<.05) (Piek, et al., 2008). Despite mixed and extremely limited evidence in preschool children with DCD (King-Dowling, et al., 2015; Piek, et al., 2008), this finding suggests the possibility that DCD and internalizing problems may co-occur from early childhood, at least as young as 3 years of age. However, there is a need for more evidence to replicate this finding in early childhood by including a larger sample, and investigate whether this relationship may be affected (i.e., mediated and moderated) by other psychosocial and physical factors that are incorporated in the ESH.

Lastly, even though the ESH was developed based on Pearlin's Stress Process model (Cairney, et al., 2013), to date, there is no study investigating whether children with DCD have higher level of stress, and conversely, a majority of researches has focused on the final outcomes which are internalizing problems (*aka*. distress) (King-Dowling, et al., 2015; Lingam, et al., 2012; Missiuna, et al., 2014; Piek, et al., 2008; Piek, et al., 2007; Pratt & Hill, 2011; Schoemaker & Kalverboer, 1994; Skinner & Piek, 2001). This is an important area in need of further research.

1.4 GENERAL PURPOSE OF DISSERTATION

Although several studies have specifically examined some pathways in the ESH in the community sample of adolescents (*for example*, Mancini, et al. (2016) and Rigoli, et al. (2012)), to the best of our knowledge, no study has been specifically investigated the association between DCD and internalizing problems testing multiple mediating/moderating pathways specified in the model.

Other considerations also warrant further research. First, whereas previous studies were more interested in the effects of the psychosocial outcomes (e.g., perceived social support or global self-worth) on childhood or adolescent internalizing problems, none has examined the sequential meditating pathways with physical activity and weight status based on the ESH (e.g., DCD → physical inactivity/obesity → psychosocial stressors → internalizing problems, *see* Figure 1), nor have the possible mediating effects of physical activity and obesity on the

relationship between DCD and internalizing problems (e.g., DCD → physical inactivity/obesity → internalizing problems).

Moreover, as child development is dynamic, the relationships among DCD, physical health, psychosocial consequences, and mental well-being (i.e., internalizing problems) described in the ESH may change over time and/or differ between boys and girls. For example, the aforementioned sex differences in physical activity and BMI (*see* Chapter 1.3.3) may be minimal during early childhood and increase in adolescence (Cairney, Hay, Veldhuizen, et al., 2010b; Joshi, et al., 2015). This pattern of development was not highlighted in the original review, but can potentially change the underlying pathways in the ESH (Cairney, et al., 2013).

Taken together, the overarching purpose of this dissertation is to investigate the relationship between DCD and internalizing problems by testing multiple pathways in the ESH, and thereby extend our understanding of the mediating role of physical activity and weight status (i.e., BMI) in the relationship between DCD and internalizing problems. Three cross-sectional studies were respectively conducted in different age groups, including early childhood, late childhood or early adolescence, and early adulthood to address these issues from a developmental perspective.

1.4.1 Study 1

Study 1 investigated internalizing problems in preschool children at risk of DCD (rDCD), and the mediating roles of physical activity and BMI in the relationship between rDCD and internalizing problems. In addition, this study was interested in the potential effects of sex on these relationships. This study addressed a limitation of previous studies with respect to the inconclusive finding whether preschool children with rDCD were at greater risk for internalizing problems by recruiting a larger number of children with rDCD (King-Dowling, et al., 2015; Piek, et al., 2008). Preliminary data were retrieved from the Coordination and Activity Tracking in CHildren (CATCH) study in which data on children's motor coordination using the Movement Assessment Battery for Children – Second Edition, physical activity using accelerometers, and BMI were collected and internalizing problems were reported by parents on the Child Behavior Checklist. It was hypothesized that preschool children with rDCD would experience more internalizing problems than typically developing preschoolers. Furthermore, physical activity and BMI were hypothesized to mediate the relationship between rDCD and internalizing problems; in other words, when compared to typically developing peers, preschool children with rDCD would have lower levels of physical activity and higher BMI, both of which would further lead to increased symptoms of internalizing problems. Sex was also considered to potentially alter these pathways.

1.4.2 Study 2

Study 2 examined school-aged children in late childhood and early adolescence. This study was built based on the framework of Study 1 and incorporated global self-worth, which has been identified as one of the strongest predictors of internalizing problems in school-aged children (Sowislo & Orth, 2013), into the model to test the partial ESH. This study sought to understand the stability of the relationship between probable DCD (pDCD) and internalizing problems and the potential mediation of physical activity, BMI, and global self-worth based on the ESH. Furthermore, as a sex by group by time effect on physical activity and BMI in school-aged children with pDCD has been observed (Cairney, Hay, Veldhuizen, Missiuna, Mahlberg, et al., 2010; Cairney, Hay, Veldhuizen, et al., 2010b), and that sex by time effects on internalizing problems have likewise been observed in community samples of older children (Cairney, 1998; Petersen, et al., 1993; Wade, et al., 2002), the possible moderating effect of sex on pathways in the ESH was also examined. This study analyzed data using the database of the Physical Health and Activity Study Team (PHAST) that used the Bruininks-Oseretsky Test of Motor Proficiency – Short form to evaluate motor coordination, the Participation Questionnaire to measure physical activity, the Harter's Self-Perception Profile for Children to measure global self-worth, and the Kessler-6 scale for internalizing problems. It was hypothesized that pDCD would initiate sequential mediating pathways leading to more internalizing problems in school-aged children (pDCD → physical inactivity/higher BMI → lower global

self-worth → internalizing problems), and that these pathways may differ between boys and girls.

1.4.3 Study 3

Study 3 was conducted to test the full ESH model in young adults. This study not only investigated if young adults with poor motor coordination experienced higher psychological distress but also was designed to test all mediating pathways in the ESH, which has not been done by any of previous studies. Participants were asked to complete an online survey consisting of a series of questionnaires regarding motor coordination, general stress, global relationships, physical activity, BMI, perceived social support, self-concept (i.e., self-esteem, mastery and self-competence), and psychological distress. Taking into account a lack of gold standard test for the diagnosis of adults with DCD, this study assessed a range of motor coordination and used the continuous variable of motor coordination, instead of the dichotomized variable of DCD. It was hypothesized that young adults with poorer motor coordination would have higher stress levels, poorer global relationships, lower physical activity, higher BMI, lower perceived social support, lower self-concept, and be at greater risk of developing psychological distress. Most importantly, these secondary physical (i.e., physical activity and BMI) and psychosocial stressors (i.e., stress, global relationships, perceived social support, and self-concept) initiated by the primary

stressor of poor motor coordination would mediate the relationship between poor motor coordination and psychological distress in young adults.

1.5 SUMMARY

Three cross-sectional studies were undertaken to examine the relationship between motor difficulties (rDCD in Study 1, pDCD in Study 2, and poor motor coordination in Study 3) and internalizing problems and the extended ESH with two direct paths connecting physical activity and BMI to internalizing problems across three different developmental periods (Studies 1-3). The first two studies utilized existing databases in preschool children (Study 1) and school-aged children (Study 2), whereas Study 3 was designed to collect data using an online survey in young adults. These studies are presented in the subsequent three chapters, followed by a general discussion summarizing how this dissertation has contributed to the understanding of the ESH at different ages.

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CHAPTER 2:

DEVELOPMENTAL COORDINATION DISORDER, PHYSICAL AND MENTAL HEALTH IN PRESCHOOL CHILDREN

Preamble

Developmental Coordination Disorder, physical and mental health in preschool children is the first study in the dissertation series. The study examines the mediation of physical activity and BMI on the relationship between Developmental Coordination Disorder and internalizing problems.

The manuscript is not currently submitted for publication in a journal and has been formatted for this dissertation.

Contribution of Study 1 to overall dissertation

Study 1 provides the evidence that preschool children at risk for DCD (rDCD) are at greater risk of internalizing problems, indicating that rDCD and internalizing problems co-occur during early childhood. However, the relationship is not mediated by physical activity or BMI. Thus, Study 1 contributes to the overall dissertation by showing the co-occurrence of rDCD and internalizing problems in preschool children as young as 4 to 5 years of age and warrants the need of further research investigating the roles of psychosocial factors in the Environmental Stress Hypothesis which were not tested in this study.

Abstract

Background and purpose: Preschool children at risk for Developmental Coordination Disorder (DCD) are more likely to experience internalizing problems, such as depression and anxiety, than typically developing preschoolers. Currently, the underlying mechanisms resulting in increased internalizing problems in DCD remains unknown; however, a previous study based on the Environmental Stress Hypothesis (ESH) indicates that physical inactivity and obesity may mediate the relationship between DCD and internalizing problems. The purpose of this study is to investigate the relationships between DCD, internalizing problems, physical activity, and BMI based on the ESH, and the role of sex in these relationships in preschool children, a population for which we currently have very limited data. **Methods:** Young children enrolled in the Coordination and Activity Tracking in CHildren (CATCH) study comprised the sample (n=211). Of these, 110 (76 boys, 69.1%) were classified as at risk for DCD (rDCD) with a score at or below 16th percentile on the Movement Assessment Battery for Children – Second Edition. Physical activity was measured using accelerometers and height and weight were measured by trained research assistants, while parents completed the Child Behavior Checklist to rate internalizing problems. **Results:** Children with rDCD reported more internalizing problems than typically developing children. While there was a direct effect of rDCD on internalizing problems (unstandardized coefficients = 4.16, p's<.01), neither physical activity nor BMI mediated this relationship. Furthermore, neither

sex nor its interactions with physical activity or BMI were found on internalizing problems. **Conclusion:** The findings from this study support co-occurring internalizing problems in preschool children with DCD, and extend these findings to demonstrate that this relationship is not explained by physical activity or BMI in early childhood. Further research should be directed towards other psychosocial factors incorporated in the ESH to better understand the underlying mechanisms between DCD and co-occurring internalizing problems.

Introduction

Developmental Coordination Disorder (DCD) is one of the most prevalent childhood neurodevelopmental disorders impacting approximately 5% of all school-aged children (APA, 2013; Barnhart, Jo Davenport, Epps, & Nordquist, 2003; Kadesjo & Gillberg, 1999; Missiuna, 1994). DCD is characterized by impaired gross and fine motor skills, leading to difficulties with motor execution of activities of daily living, such as buttoning shirts, tying shoelaces, riding a bike, and scholastic performance, such as handwriting and using scissors (APA, 2013). In addition to motor impairments, DCD is associated with an increased risk of poor psychosocial outcomes, such as poor interpersonal relations, lower self-worth or self-efficacy (Zwicker, Harris, & Klassen, 2013).

Previous studies has examined psychological problems in children with DCD, particularly depression and anxiety (Missiuna et al., 2014; Piek, Bradbury, Elsley, & Tate, 2008; Pratt & Hill, 2011; Skinner & Piek, 2001). This body of work has consistently demonstrated higher rates of internalizing problems in children with motor coordination difficulties. However, two important limitations currently exist in the literature. First, while findings in children and adolescents consistently demonstrate individuals with DCD are more likely to be anxious or depressed compared to their typically developing (TD) peers (Pearsall-Jones, Piek, Rigoli, Martin, & Levy, 2011; Piek et al., 2007; Pratt & Hill, 2011; Schoemaker & Kalverboer, 1994; Skinner & Piek, 2001), the literature in preschoolers is equivocal (King-Dowling, Missiuna, Rodriguez, Greenway, & Cairney, 2015 ;

Piek, et al., 2008). For instance, Piek and colleagues (2008) indicated that children with lower motor competence appeared to be more depressed and anxious than their peers, whereas a recent study by King-Dowling et al. (2015) did not show statistically significant group differences in internalizing problems despite more internalizing problems still reported in young children with movement difficulties. The discrepancy may be due to the relatively small number of children with DCD (14 and 37, respectively) in these studies. Taking into account the early onset of DCD (APA, 2013), it is essential to recruit a larger sample size to clarify if internalizing problems would occur with motor impairments from early childhood.

Second, the underlying mechanisms associated with internalizing problems in DCD remain unclear. To date, the Environmental Stress Hypothesis (ESH) appears to be a promising framework for identifying a number of potential pathways connecting DCD and internalizing problems through a variety of secondary physical and psychosocial stressors (Cairney, Rigoli, & Piek, 2013; Cairney, Veldhuizen, & Szatmari, 2010). The ESH extends Pearlin's Stress Process Model to illustrate potential causal pathways between DCD and internalizing problems (Pearlin, 1989; Pearlin, Menaghan, Lieberman, & Mullan, 1981). The central idea of this framework is that the primary stressor, DCD, leads to a number of interpersonal conflicts with peers, parents, and school teachers, and that these stressors expose children to a greater risk for developing mental illness, specifically internalizing problems (Cairney, et al., 2013). This central pathway, however, can also be influenced by personal resources (e.g. self-

concept) and perceived social support, both of which potentially act as mediators and moderators on the relationships between DCD, personal conflicts, and internalizing problems (Cairney, et al., 2013). A particularly novel feature of the framework is the inclusion of physical inactivity and overweight/obesity, both of which are hypothesized to arise as the secondary consequences of DCD. Physical inactivity and overweight/obesity can also impact social relations, perceived social support and self-concept, and mental health in children with DCD (Cairney, et al., 2013). Although the ESH provides a conceptual framework to examine mediating and moderating variables on internalizing problems in children with DCD, the relationships among all variables were established based on evidence from a variety of studies. At present, no study has investigated multiple pathways in this model together at the same time in either preschool or school-aged children with DCD.

As children with DCD are not usually diagnosed until school age (Barnhart, et al., 2003), and the measurement of mental health problems in preschoolers largely relies on parents' responses (King-Dowling, et al., 2015 ; Piek, et al., 2008) or observation (Kennedy-Behr, Rodger, & Mickan, 2013), research regarding the relationship between internalizing problems and DCD is relatively limited in early childhood. As longitudinal studies have shown that the early onset of motor deficits during infancy or early childhood could predict depressive and anxious symptoms in later life (Piek, Barrett, Smith, Rigoli, & Gasson, 2010; Sigurdsson, Van Os, & Fombonne, 2002), it is of importance to

understand the time-course of developing internalizing problems in children with DCD to identify a critical time period for implementing interventions in order to prevent mental health problems.

Given the paucity of research examining underlying mechanisms of internalizing problems in young children, the purpose of this study was to test a partial model based on the ESH by investigating the relationships among DCD, physical health, and internalizing problems in preschool children. A modified model of the ESH, which focuses specifically on the connections from physical activity and weight status to internalizing problems, is the focus of the present study. As noted previously, these are among the most novel constructs of the ESH and have yet to be tested in this developmental period. Research on typically developing children has already established that physical activity (Biddle & Asare, 2011; Kremer et al., 2014; Stavrakakis, de Jonge, Ormel, & Oldehinkel, 2012) and overweight/obesity (Geoffroy, Li, & Power, 2014; Hoare, Skouteris, Fuller-Tyszkiewicz, Millar, & Allender, 2014) are independently associated with internalizing problems in school-aged children and adolescents. Whether this is true in preschool children with DCD remains to be tested. We hypothesized that preschool children with DCD would participate in less physical activity, have higher BMI, and be at greater risk for internalizing problems. Furthermore, we will test whether sex effects these pathways linking DCD to internalizing problems.

Methods

Participants

This study was a cross-sectional analysis utilizing baseline data (from March 2014 to September 2015) from the Coordination and Activity Tracking in CHildren (CATCH) study. This is a prospective case-control study tracking changes in motor coordination, physical fitness, physical activity, and other health behaviours in children from preschool age into school age, currently ongoing in the INfant and Child Health Lab (INCH) (Cairney et al., 2015). In this study, 211 children (101 TD and 110 DCD) between the ages of 4 and 5 years (60.5 ± 6.7 months, 48 – 71 months) provided valid data on all measures, including motor coordination, physical activity, body composition, and internalizing problems. Informed, written consent was provided by parents or legal guardians. Ethical approval was obtained from the Hamilton Integrated Research Ethics Boards.

Procedures

The study protocol of the CATCH study has been described in detail elsewhere (Cairney, et al., 2015). Motor coordination was assessed using the Movement Assessment Battery for Children – Second Edition (MABC-2) administered by trained research assistants. The scores of the MABC-2 were calculated and used to identify whether the child was DCD ($\leq 16^{th}$ percentile). We use the term "at risk for DCD" (rDCD) in this study to describe children under 5 years of age who met the DSM-V criteria for DCD, but did not have a repeated motor assessment to

confirm all diagnostic criteria (Smits-Engelsman, Schoemaker, Delabastita, Hoskens, & Geuze, 2015). All children with rDCD were invited to join the follow-up study in which the assessments will take place once a year for five years. Children who scored >16th %iles were defined as TD, and were invited to the follow-up study. Concurrently, parents were asked to complete the Child Behavior Checklist to identify their child's emotional and behavioural problems. At the end of the visit, children in the follow-up cohort were given accelerometers to track their physical activity levels over seven days.

Measures

Internalizing problems

The Child Behavior Checklist (CBCL) is widely used to assess children's emotional and behavioural problems (Achenbach & Rescorla, 2000). The parent, in most cases the mother, was asked to rate 100 questions with respect to children's emotional symptoms and behaviours using a 3-point adjectival scale ranging from 0 (not true) to 2 (very or often true). All questions were divided into eight different syndromes, including emotional reactivity, anxious/depressive, somatic complaints, withdrawn, attention problems, aggressive behavior, and sleep problems, and raw scores for all questions were recorded to calculate the syndrome scale scores that were further used to obtain the subscores of internalizing problems, externalizing problems, as well as a total problem score. Each score was converted into T-scores to identify children in the clinical range

(>60 for internalizing and externalizing problems and total problems; >65 for eight emotional and behavioural syndromes). This study only analyzed the subscores of internalizing problems, including four emotional syndromes: emotional reactivity, anxious/depressive, somatic complaints, and withdrawn. The total subscores (T-score) and the clinical cut points for internalizing problems were used in this study. Internal consistency (Cronbach's α=0.77 – 0.79), convergence and discriminative validity of the CBCL have been validated, and test-retest reliability was found to be good to excellent (r=0.84 – 0.97) (Achenbach & Rescorla, 2000; Nakamura, Ebesutani, Bernstein, & Chorpita, 2009).

Motor coordination

The MABC-2 test includes eight testing items across three subtests and was developed to assess children's gross and fine motor skills (Henderson, Sugden, & Barnett, 2007). This study used the age band 1 (3-6 year-olds) to evaluate children's motor coordination. There are three items (posting coins, threading beads, and drawing trail) in the subtest of manual dexterity (MD), two items (catching beanbag and throwing beanbag onto mat) in the subtest of aiming and catching (AC), and three items (one-leg balance, walking heel raised, and jumping on mats) in the balance (BL) subtest. Raw scores for each item were converted into standard scores, and then summed to calculate the subtest scores and the Total Test Score (TTS). The percentile rank for the TTS was used to determine

children's motor coordination. Children scoring at or below the 16th percentile are defined as rDCD. The MABC-2 test has been validated to be an appropriate evaluation tool to assess motor coordination in preschool children (Ellinoudis et al., 2011; Henderson, et al., 2007; Hua, Gu, Meng, & Wu, 2013; Smits-Engelsman, Niemeijer, & van Waelvelde, 2011); it has excellent construct validity using confirmatory factor analysis (Schulz, Henderson, Sugden, & Barnett, 2011), and good to excellent test-retest reliability with a one- or two-week interval (r=0.83 - 0.99) (Ellinoudis, et al., 2011; Hua, et al., 2013; Smits-Engelsman, et al., 2011; Wuang, Su, & Su, 2012), as well as inter-rater reliability (ICCs=0.76 – 0.99) (Hua, et al., 2013; Smits-Engelsman, et al., 2011). Internal consistency was considered adequate to good, with Cronbach's α ranging between 0.50 and 0.87 (Ellinoudis, et al., 2011; Hua, et al., 2013; Smits-Engelsman, et al., 2011).

Physical activity

Physical activity was measured using the ActiGraph wGT3X+ Accelerometer (ActiGraph, Pensacola, FL), a small device fastened over the right hip of the child for seven consecutive days. The accelerometer was removed when children engaged in water activity and during sleeping time. Parents were provided with a log book to track the times when their child put on and removed the accelerometer, as well as the reasons for removing. Taking into account the nature of preschool children's physical activity, activity counts were recorded in 3-second epochs to more accurately measure physical activity levels (Obeid, Nguyen, Gabel, &

Timmons, 2011), and time and the percentage of wear time spent in each intensity level (i.e., light, moderate, and vigorous) of physical activity were also determined for each child . Physical activity was monitored for seven consecutive days, and valid data was defined as wear time of at least 600 minutes per day, on at least 3 days per week (Obeid, et al., 2011). This study used activity counts (i.e., counts per minute) to represent physical activity as it has been considered to be a more direct reflection of what an accelerometer measures and more sensitive to monitor the change in physical activity (Wolff-Hughes, Fitzhugh, Bassett, & Churilla, 2015).

Body composition

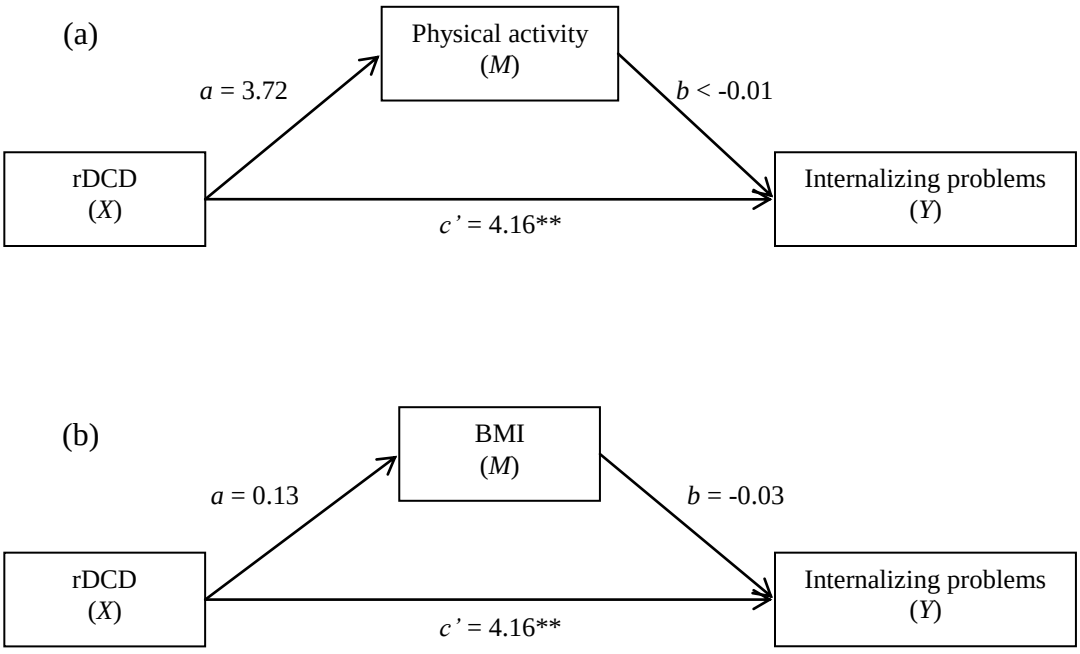
Body Mass Index (BMI) was used to assess body composition. Children's standing height was measured without shoes to the nearest 0.1 cm using a stadiometer, and body weight was measured without shoes to the nearest 0.1 kg using an electronic weight scale. The averages of two assessments for height and weight were then used to calculate BMI.

Data analysis

Statistical analysis was conducted on the SPSS version 22.0 for Windows (Armonk, NY: IBM Corp). Independent sample t-tests and Chi-square statistic were used to examine the group differences (rDCD vs. TD) in continuous variables and nominal variables, respectively. The PROCESS software macro was

used to test the indirect (mediation) effects of physical activity and BMI (*M*) on the relationship between rDCD (*X*) and internalizing problems (*Y*) (Hayes, 2013). Two single mediation models with either physical activity (Figure 1a) or BMI (Figure 1b) were tested using the bias-corrected bootstrap procedures with 10,000 simulations, and the indirect (mediation) effects were examined using the Sobel test (Hayes, 2013). Kappa-squared (k^2) values, which are analogous to $R^2$and represent the proportion of variance accounted for by the mediator, were also used to estimate the effect sizes for the single mediation models (ranging from 0 to 1; small =.01, medium =.09, and large =.25) (Hayes, 2013).

Furthermore, this study employed multiple variable regression to investigate the effect of sex on internalizing problems. First, we examined whether there was a difference in internalizing problems between boys and girls (Model 1 in Table 3). Second, rDCD was added to test for the main effects (Model 2) before the interaction of sex by rDCD was added into Model 3. Physical activity and BMI were added separately (Model 4 and 5) to examine the main effects on internalizing problems. Finally, all possible two- and three-way interactions between sex, rDCD, physical activity, and BMI were created and added into the models (Model 6 and 7 in Table 3). All variables (main effects and interactions) were mean-centered in order to reduce the multi-collinearity between the interaction terms and their components in the regression models (Aiken & West, 1991). The statistical significance was set at $\alpha < .05$.



** p<.01

Figure 1. (a) Single mediation model of physical activity; (b) Single mediation model of BMI

Results

Descriptive statistics

The results of descriptive statistics were provided in Table 1. Compared to the TD group, there were more boys in the rDCD group (69.1% vs 45.5%, x^2=11.97, df=1, p<.01). Children with rDCD scored significantly lower than TD children in the subdomains (all *p*'s<.001) and the total test score (t=19.91, df=209, p<.001) of the MABC-2 test, indicating they had more severe motor difficulties. Children with rDCD also experienced more internalizing problems (t=-3.12, df=209, p<0.01),

including emotional reaction (t=-2.17, df=209, p<.05), anxiety/depression (t=-2.04, df=208.10, p<.05), and withdrawal (t=-5.25, df=187.04, p<.001). Furthermore, the proportion of children who had internalizing problems within the clinical range was significantly higher in children with rDCD than TD controls (9.1% vs 2.0%, x^2=4.96, df=1, p<.05).

Table 1. Descriptive statistics in children with and without rDCD

	TD (n=101)	**rDCD (n=110)**
Boys (%)**,[a]	46 (45.5%)	76 (69.1%)
Age (months)	61.19±7.31	59.94±6.12
Height (cm)	110.67±6.13	110.54±6.50
Weight (kg)	19.33±2.89	19.49±3.60
BMI (kg/m^2)	15.71±1.28	15.84±1.61
MABC-2 (Standard score)		
Manual Dexterity***	31.79±4.37	20.88± 6.54
Aiming & catching***	19.50±4.26	15.17± 4.15
Balance***	30.85±4.92	19.82± 5.44
Total Test Scores***	82.15±9.08	55.87±10.01
Physical activity		
Counts per day (10^3)	507.98±134.99	504.93±143.21
Counts per minute (cpm)	696.01±179.95	699.72±199.97
CBCL (T score)		
Emotionally reactive*	2.25±1.86	2.91± 2.50
Anxious/depressed*	1.89±1.83	2.45± 2.13
Somatic complaints	1.64±1.66	2.04± 1.94
Withdrawn***	0.90±1.13	1.96± 1.77
Internalizing problems**	46.96±8.90	51.12±10.31
Clinical range*,[a]	2 (2.0%)	10 (9.1%)

[a] Chi-square statistic was used to test the group difference

Mediation of physical activity and BMI

As shown in Table 2, rDCD was only correlated with internalizing problems (r=.211, p<.01), but neither with physical activity (r=.010, p>.05) nor BMI (r=.043, p>.05). Furthermore, there was no significant correlation found between physical activity, BMI, and internalizing problems.

The results of the mediation analyses are shown in Figure 1. Direct effect path coefficients are shown in Figure 1a and 1b. In the first single mediation model with physical activity as the mediator (Figure 1a), there was a direct effect of rDCD on internalizing problems (c' = 4.16, p<.01, 95% C.I. = 1.54 – 6.79); however, there was no indirect (mediation) effect of physical activity (95% C.I. = -0.29 – 0.17; Sobel test Z = -0.06, p>.05; k^2 <0.01, 95% C.I. = 0 – 0.002). In the second model with BMI as the mediator (Figure 1b), rDCD also had a significant direct effect on internalizing problems (c' = 4.16, p<.01, 95% C.I. = 1.53 – 6.79), but BMI was not found to mediate this relationship (95% C.I. = -0.27 – 0.19; Sobel test Z = -0.03, p >.05; k^2 <0.01, 95% C.I. = 0 – 0.001).

Table 2. Bivariate correlations between rDCD, physical activity, BMI, and internalizing problems

	rDCD	Physical activity (cpm)	BMI
Physical activity (cpm)	.010		
BMI	.043	-.021	
Internalizing problems	.211**	-.032	.005

** p<.01

Moderating Effect of Sex

There was no effect of sex on internalizing problems (b=-0.50, *B*=-.025, p>.05; Model 1 in Table 3). After rDCD was added into the first model, rDCD significantly predicted internalizing problems (b=4.53, *B*=.230, p<.01; Model 2 in Table 3), and this model explained 4.1% of variance on internalizing problems. However, there was no interaction effect of sex by rDCD on internalizing problems (b=0.36, *B*=.009, p>.05; Model 3 in Table 3). Furthermore, no sex interactions with physical activity or BMI were found to significantly predict internalizing problems in preschool children.

Table 3. Regression models to predict internalizing problems in children with DCD [Estimate (S.E.)]

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
Constant	49.13 (0.68)	49.12 (0.66)	49.10 (0.69)	49.12 (0.67)	49.12 (0.67)	49.00 (0.71)	49.05 (0.69)
Boys	-0.50 (1.38)	-1.59 (1.39)	-1.58 (1.39)	-1.51 (1.42)	-1.59 (1.39)	-1.71 (1.44)	-1.64 (1.40)
rDCD		4.53 (1.37)**	4.53 (1.37)**	4.52 (1.37)**	4.54 (1.37)**	5.03 (1.41)***	4.59 (1.38)**
PA				<-0.01 (<0.01)		<0.01 (<0.01)	
BMI					-0.03 (0.46)		-0.20 (0.53)
Boys*DCD			0.36 (2.78)			0.45 (2.87)	0.41 (2.80)
Boys*PA						0.01 (0.01)	
DCD*PA						<-0.01 (0.01)	
Boys*DCD*PA						-0.03 (0.02)	
Boys*BMI							0.15 (0.99)
DCD*BMI							1.48 (1.07)
Boys*DCD*BMI							1.45 (2.01)
Adjusted R^2	-0.004	0.041	0.037	0.037	0.037	0.033	0.029

** p<.01, *** p<.001

Discussion

The ESH guided this study to examine the relationships among rDCD, internalizing problems, physical activity, and weight status. Overall, the findings from this study further support the principal pathway identified in the ESH, connecting rDCD and internalizing problems, indicating that preschool children with motor difficulties experience more internalizing problems, including emotion control, depression and anxiety, and withdrawal from social interactions. Consistent with previous findings, but contrary to our hypothesis, children with rDCD in the current study showed similar physical activity levels and BMI scores compared to TD peers (Bart, Jarus, Erez, & Rosenberg, 2011; Schott, Alof, Hultsch, & Meermann, 2007).

Similar to previous work (Piek, et al., 2008), our findings demonstrated that preschool children at risk of DCD were more likely to have increased symptoms of depression and anxiety. A novel finding of the present study was that approximately 10% of preschool children with rDCD scored in the clinical range of internalizing problems, which was significantly greater than TD controls (2%). Internalizing problems were not in the clinical range in previous studies; however, it is worth noting that the relatively small number of children in both previous studies reduced the power to detect group differences at the clinical level (King-Dowling, et al., 2015 ; Piek, et al., 2008). That our findings differ from those of King-Dowling et al. (2015) may be attributed to differences in severity of motor impairments between studies. In the present study, children in the rDCD

group had an average score at the 8th percentile on the MABC-2, compared to the 11th percentile in their study. Taken together, as depression and anxiety negatively correlate with motor skills (Piek, et al., 2008; Rigoli, Piek, & Kane, 2012), the greater number of children at the lower end of motor functioning in our study may help to explain differences between our results and other research studies. Nevertheless, given that there are only three studies including our own, investigating internalizing problems in preschool children at risk of DCD, more research is certainly needed to better understand this issue.

Piek et al. (2007) found that environment was more strongly related to internalizing problems in preschool children with DCD than genetic factors. However, genetic and/or biological risk factors still cannot be entirely ruled out (Cairney, et al., 2010). In our study, the finding that DCD and internalizing problems may concurrently exist in young children, but that physical activity and BMI do not explain differences between groups, suggests that other potential shared risk factors should be explored (Mancini, Rigoli, Cairney, Roberts, & Piek, 2016). Based on previous cohort studies, low maternal or paternal socioeconomic status (Angold, Costello, & Worthman, 1998; Lingam, Hunt, Golding, Jongmans, & Emond, 2009), (extremely or very) low birth weight (Bohnert & Breslau, 2008; Lingam, et al., 2009; Zwicker et al., 2013), and very or late preterm birth (Johnson & Marlow, 2011; Lingam, et al., 2009; Talge et al., 2010; Zhu, Olsen, & Olesen, 2012), are examples of risk-factors that have been linked to both DCD and internalizing problems, and should be explored in future work. Birth weight

in particular has been shown to be a risk factor for neuropsychological or behavioural impairments (Nosarti, 2013), and poor motor function, suggesting the potential for shared etiology. With regard to neuropsychological factors, internalizing problems have been related to dysfunction in the frontal lobe (Saridjan et al., 2014). Under-activation of the frontal-parietal region coupled to an inefficient cerebello-frontal pathway is also implicated in children with DCD when studied using neuroimaging technique (Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2009; Zwicker, Missiuna, Harris, & Boyd, 2011). However, despite dysfunction found in similar brain areas (i.e., frontal lobe) in children with DCD and those with internalizing problems, respectively, there is a lack of evidence with regard to children who present with both DCD and internalizing problems. Further studies may also employ biological markers, such as brain-derived neurotropic factors or cortisol, to detect frontal cortex or hypothalamic-pituitary-adrenal axis function in young children with DCD and internalizing problems. This may also solve the difficulty addressed by Mancini and colleagues (2016) regarding the measurement of emotional regulation in infants, and enable to conduct a long-term follow up from early developmental stage.

Interestingly, contrary to studies of school-aged children (Cairney, Hay, Faught, & Hawes, 2005; Cairney et al., 2005; Poulsen, Ziviani, & Cuskelly, 2008) and other studies focused on preschoolers (Bürgi et al., 2011; Williams et al., 2008) that consistently found lower levels of physical activity in children with DCD or poorer motor skills, preschool children at risk of DCD enrolled in this

study were not less physically active than their TD peers. In fact, this finding is consistent with Wall's (2004) skill-gap hypothesis: preschool children usually participate in less demanding free play or unstructured physical activity, so motor impairments experienced by these younger children may not hinder them from engagement in physical activity (Wall, 2004). Subsequently, overweight and/or obesity, which are associated with physical inactivity (Stodden et al., 2008) and commonly found in school-aged children with DCD (Cairney, Hay, Faught, & Hawes, 2005), may not yet be seen in preschool children at risk for DCD.

It is worth noting that, despite the lack of significant differences in physical activity and BMI between children with and without rDCD in this study, this finding highlights the need and importance for longitudinal evaluation with respect to the relationships between DCD, physical activity, weight status, and internalizing problems to gain a better understanding of the causality, including the examination of potential mediating and moderating pathways, for identifying a critical window to develop physical inactivity and overweight/obesity, and guide the interventions for preschool children at risk for DCD. The other limitation in this study is that we were unable to include psychosocial mediating and moderating variables in the ESH. Due to less developed cognitive abilities, it is notoriously difficult to measure young children's psychosocial outcomes, such as perceived social support or self-concept. However, in older children or adolescents, psychosocial factors, including self-concept (Poulsen, Ziviani, & Cuskelly, 2006; Rigoli, et al., 2012) and self-esteem (Lingam et al., 2012), have

been identified as critical mediators on the relationship between DCD/ lower motor competence and internalizing problems. Hence, further research is warranted to employ appropriate evaluations of psychosocial variables in order to test the mediating and moderating pathways introduced in the ESH.

Conclusions

In conclusion, children with motor impairments are vulnerable to internalizing problems, such as depression, anxiety, or emotional problems. This study also raises important potential implications for application of the ESH in this population. Since neither physical activity nor BMI directly impact internalizing problems or mediate the relationship between motor impairments and mental health problems in preschool children, other pathways in the ESH may be more salient in this developmental stage. Further research should incorporate social and personal resources to better understand the context of the development of mental health problems in preschool children with DCD, and consider other shared risk factors that might explain the co-occurrence of these conditions.

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CHAPTER 3:

A TEST OF THE ENVIRONMENTAL STRESS HYPOTHESIS IN SCHOOL-AGED CHILDREN WITH AND WITHOUT DEVELOPMENTAL COORDINATION DISORDER

Preamble

A test of the Environmental Stress Hypothesis in school-aged children with and without Developmental Coordination Disorder is the second study in the dissertation series. This study investigates the relationship between Developmental Coordination Disorder and internalizing problems in school-aged children and whether this relationship is mediated by physical activity, BMI, and global self-worth.
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The manuscript is not currently submitted for publication in a journal and has been formatted for this dissertation.

Contribution of Study 2 to overall dissertation

Study 2 provides the evidence showing more internalizing problems in school-aged children with probable DCD (pDCD) than their typically developing peers. In addition, the relationship between pDCD and internalizing problems is sequentially mediated by physical activity/global self-worth and BMI/global self-worth. Study 2 also extends the Environmental Stress Hypothesis by finding a direct path from physical activity to internalizing problems. Most importantly, this study highlights sex differences in the underlying mechanisms of internalizing problems in school-aged children, indicating that interventions targeting on the improvement in internalizing problems should be sex-specific.

Abstract

Background and purpose: Children with Developmental Coordination Disorder (DCD) are at an increased risk for being physically inactive, overweight, and mental health problems such as depression and anxiety. The Environmental Stress Hypothesis (ESH) proposes several causal pathways connecting DCD, physical activity, BMI, and global self-worth to internalizing problems; however, more work is required to test these pathways. The current study aims to test the relationships between probable DCD (pDCD), physical activity, BMI, global self-worth, and internalizing problems in school-aged children. **Methods:** A cross-sectional analysis involving 1206 children aged 12-14 years (79 pDCD, 6.6% of the sample) was conducted. Children received assessments of motor coordination, physical activity, BMI, global self-worth, and internalizing problems. Path analysis was conducted to examine overall model fit and sex differences. **Results:** Children with pDCD were less physically active, had higher BMI, reported lower self-worth, and experienced a greater number of internalizing problems (*p'*s<.05). A model based on the ESH showed very good fit to the data (x^2=2.970, df=2, p=0.227; RMSEA =0.020; NNFI=0.990; CFI=0.998; GFI=0.999). There was, however, a difference in overall model fit by sex (Δx^2=-16.607, Δdf=8, p<.05; ΔCFI>0.1), suggesting that the pathways may be different for boys and girls. **Conclusion:** We were able to find support for some of the pathways identified in the ESH in school-aged children. The finding that pathways connecting pDCD to

internalizing problems are different for boys and girls suggests that the development of interventions may need to be sex specific.

Introduction

Mental health problems, including emotional and behavioural problems, are common in childhood with population-based estimates suggesting that more than 800,000 (approximately 14%) 4- to 17-year-old Canadian children have a mental disorder, with anxiety being the most prevalent childhood disorder at 6.4% (Waddell, McEwan, Shepherd, Offord, & Hua, 2005). Unfortunately, the prevalence may even be increasing as a recent longitudinal study found that overall mental health-related medical use (e.g. emergency department visit, hospitalization, and outpatient care) has increased between 2006 and 2011 (Gandhi et al., 2016). In order to prevent the early onset of mental health problems, it is essential to understand both the risk and protective factors that affect the development of salient mental health issues.

Individuals with Developmental Coordination Disorder (DCD) are a specific population considered to be at greater risk of developing mental health problems (Cairney, Veldhuizen, & Szatmari, 2010). For example, children with DCD have been found to be more likely to hold negative self-perceptions, have poorer emotional health, higher rates of inattention, poorer cognitive function, greater social rejection and peer victimization, relative to typically developing children (Missiuna et al., 2014; Zwicker, Harris, & Klassen, 2013). This is concerning as DCD is one of the most common neurodevelopmental disorders in childhood (Cairney, 2015; Henderson & Henderson, 2002, 2003), affecting about 5% of all school-aged children (APA, 2013). A diagnosis of DCD is made if the

motor impairments experienced are not better explained by intellectual disability and visual impairment, and/or attributable to other neurological conditions that would affect motor ability (e.g. muscular dystrophy or cerebral palsy). Importantly, people with DCD experience difficulties in executing motor tasks associated with daily living, which may include tying shoelaces, riding a bike, or handwriting (APA, 2000, 2013). The onset of these problems occurs early in child development. As motor coordination is essential for engagement in physical activity across life span (Payne & Isaacs, 2002; Stodden et al., 2008), motor impairments during childhood and youth may subsequently impact engagement in physical activities, leading to a variety of secondary consequences, such as obesity or poor cardiovascular function (Cairney & Veldhuizen, 2013). The consequences of DCD arising from inactivity may also have a negative influence on mental health. Indeed, school-aged children with DCD have been shown to be at greater risk for emotional and behavioural problems, such as depression, anxiety, and aggression (Losse et al., 1991; Missiuna, et al., 2014; Piek et al., 2007; Pratt & Hill, 2011; Skinner & Piek, 2001). These emotional or behavioural problems have been shown to persist over time at least into adolescence (Losse, et al., 1991; Piek, Barrett, Smith, Rigoli, & Gasson, 2010).

The Environmental Stress Hypothesis (ESH) is a framework developed to examine the effects of primary and secondary stressors associated with DCD on mental health, particularly internalizing problems in children and youth (Cairney, Rigoli, & Piek, 2013). It is based on Pearlin's Stress Process model (Pearlin,

1989; Pearlin, Menaghan, Lieberman, & Mullan, 1981), which specifies both direct and indirect effects of stressors, including life events, chronic strains, or trauma (Turner, Wheaton, & Lloyd, 1995), on psychological distress through both the mediating and moderating influences of perceived social support and psychosocial resources, such as self-esteem and mastery (Pearlin, et al., 1981; Turner, et al., 1995). Cairney and colleagues (2013) extended Pearlin's model by incorporating DCD, and other risk factors known to be associated with both psychological distress and motor coordination problem (e.g., physical inactivity and overweight/obesity) into the conceptual model. The ESH posits DCD as a primary stressor, which in turn initiates a cascade of secondary stressors, increasing the risk of internalizing problems (Cairney, et al., 2013; Cairney, Veldhuizen, et al., 2010). Both social (i.e. perceived social support) and personal resources (i.e. positive self-concept) are hypothesized to play both mediating and moderating (or buffering) roles, acting to offset the potentially harmful secondary effects of DCD on internalizing problems (Cairney, et al., 2013).

One of the more novel aspects of the ESH concerns the inclusion of physical inactivity and obesity as potential mediating factors connecting DCD to internalizing problems in children. The plausibility of these pathways is supported by research in both typically developing children and those with DCD/motor coordination problems. For example, research has shown that both physical inactivity and obesity are related to higher levels of internalizing problems in children and adolescents (Biddle & Asare, 2011; Hoare, Skouteris, Fuller-

Tyszkiewicz, Millar, & Allender, 2014). Because children with DCD are more likely to be physically inactive and more than twice as likely to be overweight/obesity when compared to typically developing children (Cairney, Hay, Faught, & Hawes, 2005; Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2010; Poulsen, Ziviani, & Cuskelly, 2008; Zhu, Wu, & Cairney, 2011), an important pathway connecting DCD to internalizing problems is likely through physical inactivity and obesity (Cairney, et al., 2013). These same factors may also influence other psychosocial factors, such as perceptions of self and interpersonal and social relationships. For example, children with DCD who are more physically inactive and/or overweight/obese may experience higher levels of interpersonal conflicts, which in turn may erode their perceptions of self, increasing the risk for developing internalizing problems. Such pathways have not yet been tested in the extant literature. Understanding the mediating and moderating pathways that link DCD to internalizing problems will help to identify intervention targets for children with DCD to prevent and/or improve mental health.

Despite an emerging literature applying some aspects of the ESH to the study of mental health problems in children with motor coordination difficulties, very few studies have systematically examined multiple underlying pathways identified in the model in children and youth with DCD. The purpose of this study was to test several pathways derived from the ESH on internalizing problems in school-aged children with DCD. In particular, we focus on the mediating effects

of physical activity, body composition (i.e., BMI), and global self-worth as key pathways linking DCD to internalizing problems, building and testing a model derived from the ESH. Global self-worth was used to represent personal resources in the ESH as recent research has shown self-esteem, which is conceptually similar to global self-worth (Harter, 2012), to be a stable predictor for internalizing problems and a strong mediator of the relationship between DCD and mental health difficulties (Lingam et al., 2012; Sowislo & Orth, 2013).

Additionally, this study will test for the potential moderating effect of sex on multiple pathways in the model. Existing evidence has shown that internalizing problems are more common in adolescent girls (Cairney, 1998; Petersen et al., 1993; Wade, Cairney, & Pevalin, 2002), and that girls are more likely to be physically inactive, have higher BMI, and have lower self-worth than boys in adolescence (Payne & Isaacs, 2002). Sex may also be an important risk factor for DCD, with some studies suggesting the prevalence is higher in boys than girls (Missiuna, 1994). However, it is not clear this is necessarily so; other research has shown roughly equal numbers of boys and girls affected (Cairney, Kwan, Hay, & Faught, 2012; Missiuna, et al., 2014). Given the importance of sex to internalizing problems and the potential for sex differences in the prevalence of DCD, it may be the case that specific pathways in the model differ for boys and girls.

Methods

Participants

This study was a cross-sectional analysis using the eighth wave of the Physical Health and Activity Study Team (PHAST) project, a longitudinal study investigating health and physical activity in school-aged cohort of children from 2005 to 2009. Our sample included 1805 children between the ages of 12 and 14 years from 61 schools assessed at the beginning of the 2008/2009 school year (Wave 8 of the PHAST study). The data at this wave was selected because this was the only wave that all variables (i.e., motor coordination, physical activity, BMI, global self-worth, and internalizing problems) were assessed on all children. 1707 children were available for analysis; of these, 1325 out of them (77.6%) received a standardized assessment of motor coordination. After further excluding those participants with invalid data on internalizing problems (please see *Results*), a total of 1206 children (70.7%) were included in this analysis.

Procedures

All testing was conducted in the schools during regular school hours (9 am to 3:30 pm). Motor skills were assessed in the school gymnasium by trained research assistants using the short form of the Bruininks-Oseretsky Test of Motor Proficiency. For practical reasons, and due to the relative stability of motor performance in children during this developmental period (at least in the absence of specific interventions to improve motor function) (Cairney et al., 2010), motor

assessments were conducted only once at either Wave 3 (Fall 2005), 4 (Spring 2006) or 6 (Spring 2007) of the PHAST study. Schools were randomly assigned into 3 groups and testing occurred in blocks as described. All children completed the Participation Questionnaire measuring participation in physical activity (Hay, 1992), the Harter's Self-Perception Profile for Children measuring global self-worth (Harter, 1985), and the Kessler-6 (K6) Scale (Kessler et al., 2002), a measure of generalized psychological distress.

Measures

Kessler-6 (K6) Scale

The 6-item K6 scale was developed to measure non-specific or generalized psychological distress, consistent with internalizing problems (e.g., symptoms of negative affect and anxiety). Based on extensive psychometric analyses using item response theory methods (Kessler, et al., 2002), the K6 scale asks respondents to report the frequency which they felt nervous, hopeless, restless, depressed, worthless, and that everything was an effort in the past 30 days. The responses options are: (1) none of the time; (2) a little of the time; (3) some of the time; (4) most of the time; and (5) all of the time. Total scores range from 0 to 24 with higher scores indicating greater risk for psychological distress; a score of $\geq$13 has been used to define serious mental illness, based on validation against clinical criterion measures (Kessler et al., 2003). The K6 scale has excellent internal consistency (Cronbach's α=0.89 – 0.92), and has been found to accurately

identify individuals with anxious disorder, mood disorder, or non-affective psychosis from those without these problems in a community population with discrimination accuracy of 0.88 (Kessler, et al., 2002). Many participants in our sample (n=442, 33.4%), however, had some missing data on this measure at the individual item level. A multiple imputations method was therefore adopted to deal with this issue (the procedure is described in further detail in data analysis section below).

Bruininks-Oseretsky Test of Motor Proficiency-Short Form (BOTMP-SF)

The BOTMP is one of commonly used instruments to evaluate children's gross and fine motor skills and to identify children with motor impairments (Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2010; Crawford, Wilson, & Dewey, 2001). The short form includes 14 testing items across eight domains selected from the full scale. Agreement of the short form against the full scale is excellent (r=0.90 – 0.91) (Bruininks, 1978). Stability in percentile rankings over time was good in these data (r=0.70, p<.001) (Cairney, Hay, Veldhuizen, Missiuna, Mahlberg, et al., 2010). Raw scores for each item were converted into the standard scores based on published age-related norms. The sum of the standard scores was then converted into percentile ranks to identify children scoring in a range consistent with a diagnosis of DCD: children who scored at or below the 10^{th} percentile on the total standardized score were identified as probable DCD (pDCD). The term of pDCD

was used in this study because not all criteria of the DSM-V were met for a formal diagnosis of DCD (APA, 2013; Sugden, Chambers, & Utley, 2006).

Participation Questionnaire (PQ)

The PQ is a 63-item self-report questionnaire which measures participation in multiple domains: free play, in- or out-of-school sports teams, and sports or dance clubs and lessons (Hay, 1992). It has been widely used to investigate physical activity in school-aged children with motor impairments (Cairney et al., 2005; Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2010; Hay & Missiuna, 1998). Items are scored to create activity units or counts based on upon discrete participation in specific activities (e.g., plays basketball at recess; participated on a soccer team outside of school); activity units are then summed together as a simple count of activities. Separate scale scores were created for each domain, and a total score combining free play (discretionary) and organized sport and physical activity was then calculated; higher scores indicated higher levels of participation in physical activities. The PQ has a high two-week test-retest reliability (0.81 in children at elementary school and 0.89 in children at secondary school) (Hay, 1992). Furthermore, construct validity has been tested in the following ways: the PQ shows significant sex differences in activity levels (boys report more activity units than girls), urban/rural differences in free play (children in rural areas report more activities than children from urban areas), and a significant moderate correlation with teacher's evaluation of participation levels; higher teaching

ratings of participation are associated with higher levels of self-reported participation (r = 0.62) (Hay, 1992).

Harter's Self-Perception Profile for Children (SPPC)

The SPPC was developed to measure perceptions of self-competence in five different domains (i.e., athletic competence, social competence, scholastic competence, physical appearance, and behavioural conduct) and overall, global self-worth in children 8 to 15 years of age (Harter, 1985). Only the subscale of Global Self-Worth of the SPPC was used in this study (Harter, 1985), as this measure has been previously found to mediate the association between motor coordination problems and internalizing problems in children (Lingam, et al., 2012). Each item on the global self-worth subscale asks the child to indicate the statement which best applies to them (e.g., "Some kids are often unhappy with themselves" or "Other kids are pretty pleased with themselves"). Then, the child must choose whether the description is "sort of true for me" or "really true for me". A four-point scale is used to score each item; higher scores represent higher levels of self-worth. The internal consistency is good (Cronbach's α=0.78 – 0.87), and evidence of construct validity is available; for example there are sex differences across subscales and total scores, and a moderate correlation with the General Self-Concept Subscale of the Self-Description Questionnaires has been demonstrated (r=0.56) (Harter, 1985, 2012).

Data analysis

Descriptive statistics were conducted using SPSS version 22.0 for Windows (Armonk, NY: IBM Corp). A multiple imputation (MI) procedure (Rubin, 1987) was employed to predict missing data at the item level on the K6 scale. Initial analyses of the pattern of missing data showed a non-monotone missing pattern. Thus, a Markov chain Monte Carlo method with ten iterations was used to impute missing values for each item score of the K6 scale (Schafer, 1997). All six item scores were included into a MI model. In order to more accurately impute missing values, potential predictors of the K6 scale were separately identified using a regression analysis. Three variables (median household income, global self-worth, and generalized self-efficacy) were found to be significant predictors, and then were included in the first MI model, along with individual items from the K6 scale. Next, although sex and age were not significantly associated with the K6 score in this study, they were further added to create a second MI model to fill in missing values of item scores of the K6 scale as both factors have been previously identified to impact the distress levels in children and/or adolescents (Petersen, et al., 1993; Rao & Chen, 2009; Wade, et al., 2002). As suggested by Rubin (1987), missing values were imputed using a procedure involving five iterations to generate five complete datasets (i.e., five imputations) for both MI models.

After imputing missing data on the K6 scale, independent sample t-tests and Chi-square test were used to examine group differences in anthropometric variables between children with and without pDCD. Path analysis to examine the

ESH was then conducted using LISREL 9.2 for Windows (Scientific Software International, Inc.). The collinearity and normality of variables were first examined. The constraint method was employed to compare model fits across different models; the coefficients of the pathways that were not examined were constrained to zero (Kline, 2015). The model based directly on the ESH model outlined in Cairney et al. (2013) was first tested (see Figure 1 without the dash-line pathways). Modification indices and standardized residuals of overall model fit statistics were used to assess model fit and to provide direction for alternate models. After initial testing, the models specifying different pathways between physical activity and BMI and internalizing problems were tested (pathways (c1) and (c2) in Figure 1). Three models (with pathway (c1) only, with pathway (c2) only, and with both pathways) were then built and compared to the first model to examine if model fit significantly improved.

Model fit indices including x^2 statistics, goodness-of-fit index (GFI), comparative fit index (CFI), non-normed fit index (NNFI), and root mean square error of approximation (RMSEA), were used. Model fit between the observed and hypothesized models was considered satisfactory when the following criteria were met: (1) $p > .05$ for x^2 statistics, (2) GFI > .90, (3) CFI > .90, (4) NNFI > .90, and (5) RMSEA < .06 (Hu & Bentler, 1999; Kline, 2015). The squared multiple correlations ($Rsmc^2$) was used to indicated the amount of the variance in internalizing problems that was accounted for by the model. Furthermore, a Chi-square difference test and the difference in CFI between hierarchical models were

calculated. If p<.05 for Δx^2 statistics and/or ΔCFI>.01, then a statistically significant difference between the models was observed (Cheung & Rensvold, 2002).

Based on the previously identified model, a multi-sample analysis was used to test model stability across groups (boys and girls). We began with the baseline model without any constraint for both boys and girls in which all parameters were free to vary across groups. Next, the constraint models with constraints of different parameters were created, and all paths were fixed to be identical across groups. Finally, a Chi-square difference test and the difference in CFI between the baseline and constraint models were calculated. A significant difference between the baseline and constraint models would mean that model fit was variant between boys and girls. All significant statistical difference was set at α level <.05.

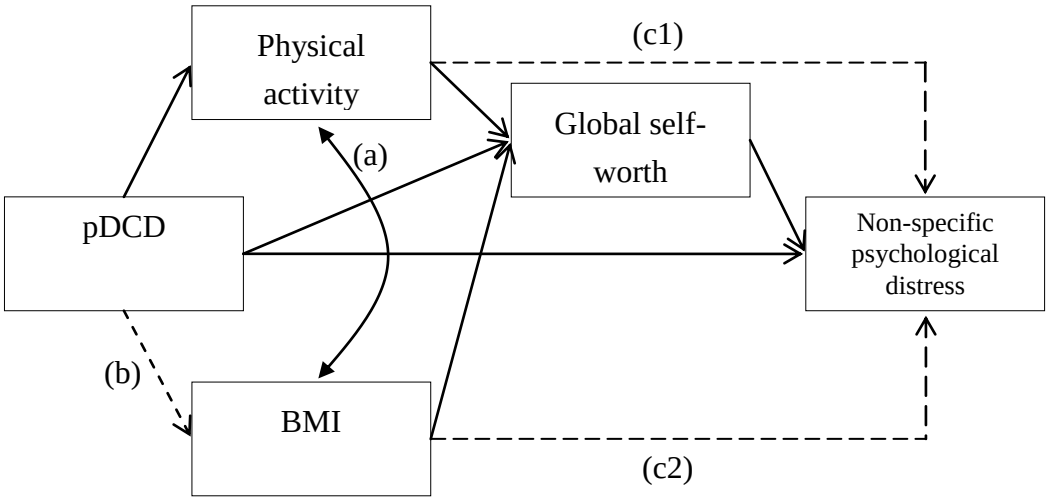


Figure 1. Pathways of the ESH

Results

Descriptive statistics

The pattern of missing values was first analyzed, and there were 188 (14.2%) missing values on the first item, 144 (10.9%) on the item 2, 173 (13.1%) on the item 3, 176 (13.3%) on the item 4, 209 (15.8%) on the item 5, and 164 (12.4%) on the item 6. Two MI models (with and without sex and age as predictors) were conducted in children who had less than three missing questions (n=353), respectively. Both models generated similar results; therefore, the imputed values derived from the first model with median household income, global self-worth and generalized self-efficacy as predictors were used in all analyses.

Compared to children without pDCD, fewer boys (x^2=5.445, df=1, p<.05) and more children with serious mental illness (x^2=14.737, df=1, p<.01) and higher levels of internalizing problems (*t* statistic=-3.210, df=82.734, p<.01) were found in the pDCD group. Children with pDCD also had significantly higher body weight (*t* statistic=-5.150, df=83.274, p<.001) and BMI (*t* statistic=-6.467, df=83.699, p<.001), and reported significantly lower levels of physical activity (*t* statistic=7.608, df=98.254, p<.001) and global self-worth (*t* statistic=2.648, df=84.144, p<.05). No significant differences between groups were found for age or body height. Details of all descriptive characteristics are shown in Table 1. None of variables showed significant problems with collinearity (variance inflation factor >10), skewness (skewness > 3) or kurtosis (kurtosis > 10) (Kline, 2015) so no transformations were required for path analysis.

Table 1. Descriptive data in children with and without pDCD

	TD (n=1127)	pDCD (n=79)	*t* value (df=1204)
Boys (%)*	581 (51.6%)	30 (38.0%)	N/A
Age (yr)	13.40±00.33	13.45±00.38	-1.316
Height (cm)	160.75±07.75	160.37±08.07	0.418
Weight (kg)***,[a]	54.14±12.32	64.66±17.87	-5.150
BMI (kg/m^2) ***,[a]	20.84±03.93	24.90±05.49	-6.467
PQ			
Free play***	10.05±3.15	8.49±3.33	4.232
Organized activity***,[a]	4.09±3.96	1.62±1.92	10.011
Total physical activity***,[a]	14.13±5.88	10.11±4.44	7.608
SPPC			
Global self-worth*,[a]	20.23±3.42	18.83±4.61	2.648
K6			
Total score**,[a]	5.48±4.14	7.80±6.34	-3.210
Serious mental illness (%)**	73 (7.0%)	15 (19.0%)	N/A

† p<.10, *p<.05, **p<.01, ***p<.001

[a] Lavene's test for equality of variances was significant.

PQ, Participation Questionnaire; SPPC, Harter's Self-Perception Profile for Children

Testing of the ESH

The first model (see Figure 1 without dashed lines) based on the original ESH showed poor model fit (x^2=77.338, df=3, p<.001; RMSEA =0.143; NNFI=0.472; CFI=0.842; GFI=0.976; Table 2). This model was then modified and further tested, taking into account the pathways from physical activity and BMI to internalizing problems. The final model with the best model fit (x^2=2.970, df=2, p=0.227; RMSEA =0.020; NNFI=0.990; CFI=0.998; GFI=0.999) is presented in Table 2. This model, accounting for 21.7% of variance in internalizing problems in school-aged children, included two direct pathways from pDCD to BMI (pathway (b) in Figure 1) and from physical activity to internalizing problems (pathway (c1) in Figure 1); however, the correlation between physical activity and

BMI (pathway (a) in Figure 1) was not significant. Based on this model, the sex difference in model fit was tested using the multiple-sample analysis.

Testing for sex-specific pathways in the ESH

As shown in Table 3, boys were significantly more physically active ($p<.01$) and had lower levels of internalizing problems when compared to girls ($p<.001$). The result of the multiple-sample analysis revealed significant differences in x^2 statistics ($\Delta x^2=-16.607$, $\Delta df=8$, $p<.05$) and CFI ($\Delta CFI>.01$) (Table 2), indicating that model fit varied between boys and girls.

The overall associations of the ESH in boys and girls are depicted in Figure 2 and Figure 3, respectively. In both boys and girls, the sequential mediating effects of physical activity/global self-worth and BMI/global self-worth were found on the relationship between pDCD and internalizing problems, indicating that school-aged boys and girls with pDCD had lower physical activity levels and higher BMI, both of which in turn led to lower global self-worth and more internalizing problems. In girls, there were a direct, residual effect of pDCD ($b=1.63$, $\beta=0.09$, $p<.01$, Figure 3) and two single-mediator pathways through physical activity and global self-worth, respectively, all of which were not observed for boys.

Table 2. The goodness-of-fitness indices in all models

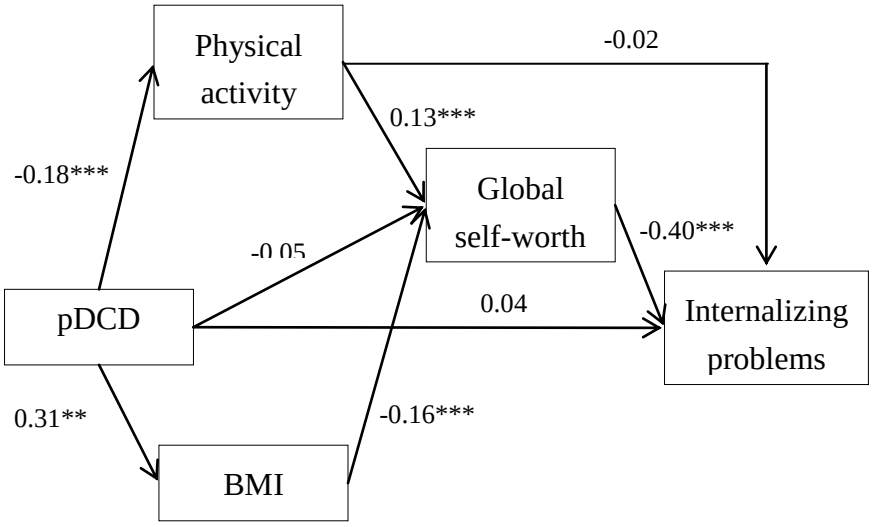
	x^2 (df, p value)	RMSEA	NNFI	CFI	GFI	$Rsmc^2$	Δx^2 (Δ df, p value)	Δ CFI
Single sample								
First model	77.338 (3, p<.001)	0.143	0.472	0.842	0.976	0.211		
Final model	2.960 (1, 0.085)	0.040	0.958	0.996	0.999	0.217		
Multiple-sample								
Baseline model	4.084 (4, 0.395)	0.006	0.999	1.000	0.998			
Constraint model	20.691 (12, 0.055)	0.035	0.970	0.982	0.993		-16.607 (8, p<.05)[a]	0.018[a]

[a] Compared to the baseline model

Table 3. Sex differences in body composition, physical activity, self-worth, and internalizing problems

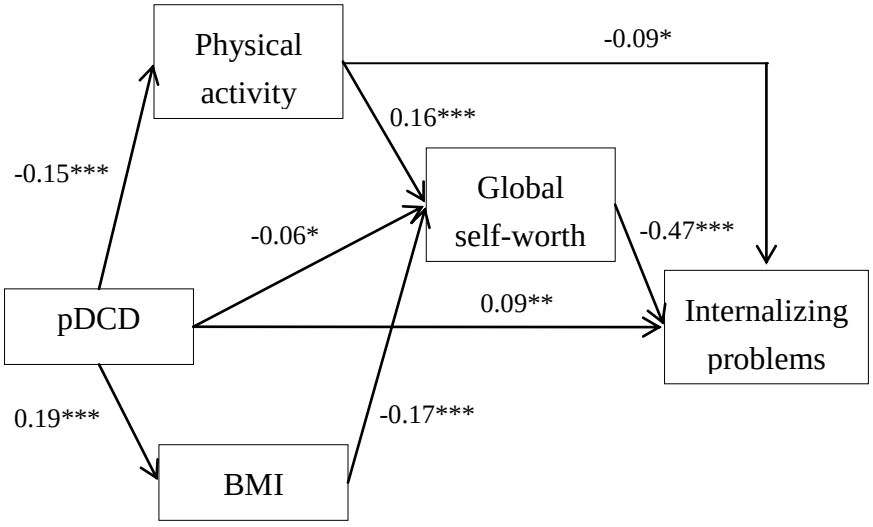
	Boys (n=611)	**Girls (n=595)**	***t* value (df=1204)**
Physical activity**	14.43±5.97	13.30±5.73	3.339
BMI (kg/m^2)†	20.88±4.03	21.33±4.30	-1.854
Global self-worth†	20.31±3.43	19.97±3.62	1.660
Internalizing problems***	5.16±4.13	6.11±4.53	-3.772

†p<.10, **p<.01, ***p<.001



** p<.01, *** p<.001

Figure 2. The ESH in boys (standardized coefficients were reported)



*p<.05, **p<.01, *** p<.001

Figure 3. The ESH in girls (standardized coefficients were reported)

Discussion

Consistent with previous studies (Missiuna, et al., 2014; Pearsall-Jones, Piek, Rigoli, Martin, & Levy, 2011; Piek, et al., 2007; Pratt & Hill, 2011; Schoemaker & Kalverboer, 1994; Skinner & Piek, 2001), our findings showed school-aged children with pDCD experienced higher levels of non-specific psychological distress, and were at greater risk for severe mental illness (i.e., K6 score $\geq$13) than their typically developing peers. We attempted to assess potential mediating factors that could explain higher rates of internalizing problems in school-aged children with pDCD. To guide this, we employed the ESH framework for the selection and testing of potential mediating effects. Overall, the findings provide some support for the model as originally proposed by Cairney et al. (2013);

however, there are two important differences. First, unlike the model presented by Cairney et al., our results suggest that there may be a fully mediating effect of physical activity on the relationship between pDCD and internalizing problems. In Cairney et al., the effect of physical activity was itself mediated through secondary stressors and psychosocial resources such as self-concept. Whether there is a direct effect remains to be tested in future research. Importantly, our study did not include measures of stress or other psychosocial resources (e.g., perceived social support) so we cannot conclude that the effect of physical activity is not mediated through these other mechanisms.

Second, while the original ESH model did not specify different pathways for boys and girls with regard to mediating effects, our results suggest the mediating pathways connecting DCD to internalizing problems may vary by sex. Despite a large body of literature investigating the issue of internalizing problems in school-aged children with DCD (Missiuna, et al., 2014; Pearsall-Jones, et al., 2011; Piek, et al., 2007; Skinner & Piek, 2001), few studies have systematically compared the impact of sex. Given that the prevalence of depression rises significantly in adolescence for girls relative to boys (Cairney, 1998; Petersen, et al., 1993; Stunkard, Faith, & Allison, 2003; Wade, et al., 2002) and that girls have lower level of perceived global self-worth, especially for those with poor motor coordination (Harter, 1987, 2012; Rose, Larkin, & Berger, 1997), it is surprising so little attention has been directed toward potential sex differences during this critical developmental period. In our study, pathways connecting pDCD to

internalizing problems through physical activity, BMI and global self-worth were not the same across sexes. For boys, pDCD is associated with increased BMI and lower levels of physical activity, both of which are negatively associated with global self-worth, which in turn is associated with higher levels of internalizing problems. For girls, these pathways are also operative, but there is also a direct, residual effect of pDCD on internalizing problems, as well as a direct effect of physical activity on mental health. This suggests that factors other than physical activity, BMI and global self-worth may have important mediating effects connecting pDCD to internalizing problems in girls. For example, poor motor coordination could negatively impact adolescent girls' self-care skills, such as dressing or applying make-up (Kirby, Sugden, Beveridge, & Edwards, 2008), which may particularly lead to lower self-perceptions of physical appearance in adolescent girls with pDCD. Negative perceptions of physical appearance may in turn result in more internalizing problems by exerting a negative impact on global self-worth (Piek, Dworcan, Barrett, & Coleman, 2000; Poulsen, Ziviani, & Cuskelly, 2006; Rose, et al., 1997; Skinner & Piek, 2001). Further work should explore these potential candidate variables, while also including more direct measures of stress and other psychosocial resources (e.g., perceived social support), identified in the ESH.

The finding that the relationship between pDCD and internalizing problems is fully and sequentially mediated by physical activity/BMI and global self-worth in boys partially supports the findings from other studies (Poulsen, et

al., 2006; Poulsen, Ziviani, & Cuskelly, 2007). Poulsen and colleagues theorize that male school-aged children from Western countries tend to prioritize participation in physical activity and sports, thus poor motor skills may hinder them from engaging in social-physical activities, which in turn hinders the development of positive self-concept and overall positive mental well-being (Poulsen, et al., 2006, 2007). Our results stress the importance for boys with pDCD to engage in active pursuits as this was significantly related to global self-worth. More research is required to replicate current findings, accounting for the potential of other pathways from DCD.

The importance of physical activity participation for both boys and girls, albeit in slightly different ways, supports the overall importance of physical activity to mental well-being in children with and without DCD. In the literature, exercise and physical activity have been shown to have both antidepressant and anxiolytic effects by releasing norepinephrine and endogenous opioid activity in the brain (Lawlor & Hopker, 2001; Salmon, 2001). Moreover, participating in physical activity is considered as one of coping strategies that helps individuals distracted from negative thoughts or events and enhance social interactions (Salmon, 2001). As a result, children with pDCD may be able to improve mental health via participation in physical activity.

The saliency of global self-worth was highlighted in the current study. Specifically, not only was global self-worth the strongest predictor of internalizing problems, accounting for about 20% for the variance, but was found

to be a significant mediator in the pDCD-internalizing problems relationship for both boys and girls. While a recent meta-analysis suggests that the relationship between self-worth and internalizing problems is robust and consistent (Sowislo & Orth, 2013), our findings were the first to examine the complex meditational pathways for children with pDCD. These results suggest that increasing global self-worth should be considered an intervention target for children with pDCD, as this may mitigate their risk of developing internalizing problems. This may include purposeful programs aimed at increasing mastery over general and specific movement skills, with the hope that children with DCD may experience improvement in physical self-concept and increased confidence to engage in more physical and social pursuits (Piek, et al., 2000; Skinner & Piek, 2001). Programs, such as *Cognitive Orientation to Daily Occupational Performance* (Polatajko et al., 2001) and *Animal Fun* (Piek et al., 2015), demonstrate that with proper support, children with DCD can acquire core motor skills, which translate into an improved sense of mastery and higher perceived motor competence. Research testing whether this can in turn lead to improvements in global self-worth remains to be tested.

Despite this being one of the most comprehensive examinations of the ESH, there are several limitations that should be acknowledged. First, the results were based on cross-sectional analyses, thus we cannot establish causation with these data. Furthermore, it limits our ability to identify how early these relationships may emerge and how they may change over time across the

childhood period. Therefore, longitudinal research is strongly recommended to examine the causal pathways linking DCD to internalizing problems based on the ESH. Second, this was only a partial test of the ESH. Because stress itself, the secondary stressors that arise from DCD identified in the ESH, was not measured in this study, several pathways cannot be examined; for example, the direct effect of pDCD on interpersonal conflicts, the mediation and moderation of children's self-concept, and the buffering effect of physical activity on the stress process. More research with complete measures identified in the ESH is required.

Conclusions

The current study not only supports several pathways in the ESH, but also enhances our understanding of the model by revealing sex differences in underlying pathways in school-aged children. Our results suggest that interventions, in addition to conventional motor training programs, should also focus on physical and psychosocial well-being, such as participation in physical activities and the establishment of global self-worth. Most importantly, sex should be taken into account while developing interventions targeting their mental health problems.

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CHAPTER 4:

MOTOR COORDINATION PROBLEMS AND PSYCHOLOGICAL DISTRESS IN YOUNG ADULTS: A TEST OF THE ENVIRONMENTAL STRESS HYPOTHESIS

Preamble

Motor Coordination Problems and Psychological Distress in Young Adults: A Test of the Environmental Stress Hypothesis is the third study in the dissertation series. This study is the most comprehensive investigation of all potential mediating pathways in the Environmental Stress Hypothesis (ESH). Specifically, Study 3 examines the mediating effects of physical health (i.e., physical activity and BMI), secondary stressors (i.e., general stress and global relationships), and psychosocial health (i.e., perceived social support and self-concept) on the relationship between poor motor coordination and psychological distress in young adults.

The manuscript is not currently submitted for publication in a journal and has been formatted for this dissertation.

Contribution of Study 3 to overall dissertation

Study 3 replicated the findings from Studies 1 and 2 showing the link between poor motor coordination and psychological distress. This study provides the evidence that young adults with poorer motor coordination have higher levels of general stress, poorer global relationships, lower levels of perceived social support and self-concept, and higher distress. Furthermore, Study 3 supports the mediating pathways of secondary stressors, perceived social support, and self-concept in the ESH. However, our findings suggest that physical activity and BMI are not the mediators of the relationship between poor motor coordination and psychological distress in young adults.

Abstract

Background: The Environmental Stress Hypothesis (ESH) illustrates the relationship between Developmental Coordination Disorder (poor motor coordination) and internalizing problems in children and youth and how the relationship may be affected by other physical health and psychosocial factors. However, to date there is a lack of evidence systematically investigating this model. Therefore, the purpose of this study is to test a comprehensive model based on the ESH in young adults. **Methods:** 225 young adults at ages of 17-23 years were recruited. Participants were requested to complete a survey regarding their motor coordination, physical activity, general stress, global relationships, perceived social support, self-concept, and psychological distress. Structural equation modeling was conducted to examine the model fit, and model fit indices were reported. **Results:** The modified original model of the ESH showed good model fit (x^2=83.24, p<.01; RMSEA=.056; NNFI=.927; CFI=.954; GFI=.947), and indicated that the relationship between poor motor coordination and psychological distress were mediated by secondary stressors (i.e., general stress and global relationships), perceived social support, and self-concept. **Conclusions:** This study highlights the effects of poor motor coordination on mental health problems in young adults, and illustrates the underlying mechanisms of psychological distress in adults with poor motor coordination. The results suggest that interventions should target psychosocial well-being, in addition to motor coordination, to prevent or improve mental health problems.

Introduction

A number of recent studies have found a positive relationship between poor motor coordination and mental health problems within community samples (Lingam et al., 2012; Piek, Barrett, Smith, Rigoli, & Gasson, 2010; Rigoli, Piek, & Kane, 2012). Specifically, children with motor coordination problems such as Developmental Coordination Disorder (DCD) have been found to be at greater risk for depression and/or anxiety compared to their typically developing peers (Missiuna et al., 2014; Pearsall-Jones, Piek, Rigoli, Martin, & Levy, 2011; Piek, Bradbury, Elsley, & Tate, 2008; Pratt & Hill, 2011; Skinner & Piek, 2001). The early onset of motor coordination problems has also been linked to symptoms of psychological distress in later adolescence or adulthood (Piek, et al., 2010; Sigurdsson, Van Os, & Fombonne, 2002). DCD is one of the most prevalent neurodevelopmental disorders in childhood and is estimated to affect 5-6% of school-aged children (APA, 2013). Children with DCD have profound motor difficulties that interfere with tasks or activities of daily living both at home and school (APA, 2013), which may consequently cause several secondary health concerns, such as negative self-perceptions (Skinner & Piek, 2001), reduced physical activity participation and poor health-related physical fitness (Cairney & Veldhuizen, 2013).

The Environmental Stress Hypothesis (ESH) was developed to explain the complex inter-relationships between DCD (or motor coordination problems) and internalizing problems, such as depression and anxiety (Cairney, Rigoli, & Piek,

2013). Internalizing problems are considered to be mediated and/or moderated by other physical (i.e., physical activity and overweight/obesity) or psychosocial (i.e., interpersonal conflicts, perceived social support, and self-concept) factors (Cairney, et al., 2013), which is consistent with Pearlin's Stress Process model (Pearlin, 1989; Pearlin, Menaghan, Lieberman, & Mullan, 1981). According to this model, DCD is considered as a primary stressor that initiates a cascade of other stressors (i.e., interpersonal conflicts as described in model), which negatively impacts other psychosocial and behavioural risk factors known to be associated with increased symptoms of internalizing problems (Cairney, et al., 2013; Cairney, Veldhuizen, & Szatmari, 2010). For example, it is hypothesized that both perceived social support and self-concept mediate and moderate the relationship between stress and internalizing problems (Cairney, et al., 2013). Physical inactivity and obesity, both of which are considered to be consequences of DCD (Cairney & Veldhuizen, 2013), may further deteriorate peer relationships, perceived social support and self-concept, and lead to greater risk for internalizing problems in children with DCD (Cairney, et al., 2013).

Despite evidence supporting some of the underlying pathways in the ESH (see Mancini, Rigoli, Cairney, Roberts, & Piek (2016) for a recent review), there is much research that still needs to be done. To date, there have only been a few studies that directly examine the relationship between DCD or poor motor coordination and internalizing problems based on the ESH (Mancini, Rigoli, Heritage, Roberts, & Piek, 2016; Rigoli et al., in press; Rigoli, et al., 2012; A.

Wilson, Piek, & Kane, 2013). For example, Rigoli et al. (2012) and Mancini et al. (2016) identified the mediating effects of self-perceptions and perceived social support on relationship between poor motor coordination and internalizing problems, respectively, in Australian adolescents (Mancini, et al., 2016; Rigoli, et al., 2012). However, our understanding of the impact of poor motor coordination on mental health problems in other populations (e.g., young children; adults) is extremely limited. Moreover, multiple mediators (e.g. stress, perceived social support, or self-competence) have not yet been simultaneously examined, and the full scope of the ESH has yet to be tested. Furthermore, as noted by Cairney et al. (2013), the direct effects of physical activity and BMI on internalizing problems that have been ascertained by previous systematic reviews (Biddle & Asare, 2011; Hoare, Skouteris, Fuller-Tyszkiewicz, Millar, & Allender, 2014), and their mediating effects on the relationship between motor coordination and internalizing problems, have not been examined. Our previous findings have indicated that physical activity may have a direct effect on internalizing problems and mediate the relationship between DCD and internalizing problems in school-aged girls (Li et al., 2016). Therefore, it is critical to investigate if the model fit of the ESH could be further improved by adding these pathways from both physical activity and BMI to mental health problems.

Both DCD and internalizing problems (symptoms of depression and anxiety) has been found to track from childhood through adolescence into adulthood (Rasmussen & Gillberg, 2000). Findings from a previous 10-year

longitudinal study found that the 16-year-old adolescents who were diagnosed as "clumsy" at the age of 6 years still experienced difficulties with motor coordination and participation in physical education classes while in high school, and in general had lower physical self-concept, and that they had more emotional and behavioural problems than their typically developing counterparts (Losse et al., 1991; Rasmussen & Gillberg, 2000). Although it is likely that the impact of poor motor coordination will persist past the transition beyond high school, little research has focused specifically on adults with motor difficulties, specifically DCD (Hill & Brown, 2013; Kirby, Sugden, Beveridge, & Edwards, 2008). The ESH represents a useful framework to begin to understand the underlying mechanisms of internalizing problems for adults with DCD.

The purpose of the present study is to examine the mediating pathways arising from motor coordination problems, through stressors, and psychological distress in ESH among young adults. We do not use the term "internalizing problems" in reference to adult mental health. Depression and anxiety are clinical diagnoses whereas the term "psychological distress" is used to describe symptoms of negative affective and anxiety (Pearlin, 1989). To be consistent with the literature, we adopt the latter term for this study. Based on the ESH, this study hypothesized that lower levels of motor coordination would lead to physical inactivity and higher BMI in young adults, all of which further increase their general stress and poor social relationships. These primary and secondary

stressors would further erode social and personal resources, and consequently, result in increased distress.

It is also well documented that sex/gender is related to depression and anxiety (Cairney, 1998; Petersen et al., 1993; Wade, Cairney, & Pevalin, 2002), and that it has also been found to influence several pathways in the ESH (Li, et al., 2016). Using a sample of opposite-sex twins (Kendler & Gardner, 2014), a recent study has identified the mechanisms of major depression to be different for males and females. Specifically, interpersonal conflicts and lower perceived social support may be strong predictors of major depression for women, whereas lower global self-worth (i.e., self-esteem) contributed more strongly in men. In light of these studies, we also investigated potential differences in pathways in the ESH on the basis of sex.

Methods

Participants

Undergraduate students at a mid-size Canadian university were recruited for the current study. A total of 241 students agreed to participate and responded to the online survey. Participants with intellectual disability, neurological/musculoskeletal disease, or physical impairments contributing to significant motor difficulties, or if they provided invalid (e.g., evidence of response bias) or incomplete data (>50% missing values) were excluded from the study. After applying the exclusion criteria, the final study sample included 225

participants (93.4%). The mean age of the sample were 19.5 years (range = 17 to 23), and the majority were female (75.1%) and in their first year of study (53.8%). Ethical approval was obtained from the Institutional Research Ethics Board.

Procedures

Participants were recruited from three sources: (1) posters placed around campus and postings on social media, (2) announcements made in undergraduate classes, and (3) recruitment stations in university residences. Eligibility was confirmed using a screening email to exclude participants with any neurological/musculoskeletal disease and visual impairment. Intellectual disabilities were not formally measured in this study because we assumed that people attending higher education would not have significant intellectual impairments (Kirby, et al., 2008). Participants were then provided with a secure online link to complete a survey with online informed consent. The first section of the survey assessed participants' demographic information (e.g., sex, date of birth, height, and weight). Participants then completed a series of items measuring motor coordination, physical activity, stress and global relationships, perceived social support, self-concept, and internalizing problems, respectively. It took participants approximately 40 minutes to complete the questionnaires.

Measures

Psychological distress

The 6-item Kessler-6 (K6) scale was developed to measure non-specific psychological distress based on extensive psychometric analysis using item response theory methods across sociodemographic subsamples (Kessler et al., 2002). The K6 scale asked respondents to self-report the frequency (none of the time to all of the time) which they felt nervous, hopeless, restless, depressed, worthless, and that everything was an effort in the past 30 days. Each response was assigned a value from 0 to 4, yielding a total score ranging from 0 to 24 with higher scores indicating a greater risk for psychological distress (Kessler et al., 2003). The K6 scale has been found to have excellent internal consistency (Cronbach's α=0.89 – 0.92), and precisely discriminate individuals with an anxiety disorder, mood disorder, or non-affective psychosis from those without these problems in the community population with discrimination accuracy of 0.88 (Kessler, et al., 2002). Internal consistency within our sample was very good (Cronbach's α=0.84).

Motor coordination

The Adult Developmental Coordination Disorder/Dyspraxia Checklist (ADC) was developed to screen for adults with DCD over 16 years of age (Kirby, Edwards, Sugden, & Rosenblum, 2010). The 40-item ADC consists of two subscales which ask adolescents or adults to report the frequency (0=never, 1=sometimes,

2=frequently, and 3=always) of childhood motor difficulties (Section 1), and current difficulties with motor tasks and activities of daily living (Section 2). The total score is the sum of two section scores, with higher scores indicating poorer motor performance. An individual is identified as having possible DCD if they show past motor difficulties in childhood (score≧17 in Section 1) and have a total score of ≧65. However, in the absence of diagnostic criteria and a gold standard test of motor coordination for adults with DCD (Hands, Licari, & Piek, 2015), this study used a continuous variable of self-reported motor coordination problems (i.e., the total scores of the ADC) as alternative to a dichotomous classification of DCD commonly used in studies of children and youth. Cronbach's α of the ADC subscales ranged from 0.87 to 0.91, indicating excellent internal consistency (Kirby, et al., 2010). Construct validity and concurrent validity against the Handwriting Proficiency Screening Questionnaire have also been validated by Kirby and colleagues (2010). Internal consistency for the ADC total scale and subscales in the current study were 0.76 for Section 1, 0.88 for Section 2, and 0.90 for the full scale.

Physical activity

The International Physical Activity Questionnaire-Long Form (IPAQ-LF) was used to measure physical activity (Booth, 2000). The IPAQ-LF is a 7-day recall self-reported questionnaire investigating habitual physical activity in 15- to 69-year-old youths and adults, and has proven to have good test-retest reliability and

criterion validity when compared against accelerometry (Craig et al., 2003). It consists of 27 questions across five domains: job-related physical activity (7 items), transportation physical activity (6 items), domestic physical activity (6 items), leisure-time physical activity (6 items) and time spent sitting (2 items). Time spent in each activity is recorded and then calculated as metabolic equivalent minutes per week (MET-min/week). The sum of MET-min/week in each activity was calculated to be representative of total physical activity and analyzed in this study.

BMI

Participants were asked to self-report body height (in either cm or ft/in) and weight (in either kg or lb). The units were further standardized into cm for height and kg for weight to calculate BMI (kg/m^2). Self-reported BMI is considered as a proxy measure of body composition that is commonly used in community samples, and it has been found to be highly correlated with objectively-measured BMI (r=0.90 – 0.95) (McAdams, Van Dam, & Hu, 2007).

Secondary stressors

Two measures were used to assess general stress and global relationships that were representative of secondary stressors in this study (i.e., interpersonal conflicts in the ESH). A measure of chronic strains (ongoing problems) from the National Population Health Survey (Cycle 1) were used to measure general stress

(Statistics Canada, 2007). Participants were asked to indicate (yes or no) on 11 items if they experienced different kinds of stress in the different domains of health, including physical, emotional, and mental well-being. Internal consistency of this questionnaire was 0.69 in this study.

Furthermore, we used the Experiences in Close Relationships – Relationship Structures (ECR-RS) to measure stressors related to intimate relationships in this study (Fraley, Heffernan, Vicary, & Brumbaugh, 2011). The self-report ECR-RS was designed to assess two dimensions, including attachment-related anxiety (e.g., I'm afraid that other people may abandon me) and avoidance (e.g., I usually discuss my problems and concerns with others). The ECR-RS includes nine items (three items for attachment-related anxiety and six items for attachment-related avoidance). Composite scores and total score were calculated by averaging the total item scores in each subscale and all questions, respectively; higher scores indicate poorer or strained relationships. The ECR-RS has demonstrated high internal consistency in previous studies (Cronbach's α=0.80 – 0.88), and there is empirical support for aspects of construct validity (e.g., factor structure and sex differences in reporting) (Fraley, et al., 2011). Internal consistency of the ECR-RS was good in this study (Cronbach's α=0.87 for avoidance domain and 0.89 for anxiety domain).

Social and personal resources

Self-esteem (six items) and mastery (seven items) were derived from work of Rosenberg (1965) and Pearlin (1981), respectively (Pearlin, et al., 1981; Rosenberg, 1965). These scales are commonly used in stress process studies as core psychosocial resources (Bovier, Chamot, & Perneger, 2004; Pearlin, et al., 1981). Self-competence was measured using the 8-item self-competence subscale of the Self-Liking and Self-Competence Scale – Revised Version, reduced from the original 20-item instrument assessing global self-esteem (Tafarodi & Swann, 1995, 2001). Confirmatory factor analysis identified construct, convergent, and discriminative validity of the scale in undergraduate students, and specifically, the subscale of self-competence showed satisfactory internal consistency and 3-month test-retest reliability (Tafarodi & Swann, 2001). The values of Cronbach's α were 0.64 for self-esteem, 0.62 for mastery, and 0.80 for self-competence in this study.

The Multidimensional Scale of Perceived Social Support (MSPSS) was also included in this study (Zimet, Dahlem, Zimet, & Farley, 1988). Participants were asked to answer 12 questions covering three different domains: support from family, friends, and a significant other. Respondents responded to each item using a seven-point Likert scale from 1 (very strongly disagree) to 7 (very strongly agree). The subscale and total scores were calculated by averaging the item scores in each subscale and the whole test, respectively, with higher scores indicating higher levels of perceived social support. This questionnaire has been validated in adolescents and young adults aged 17-22 years (Zimet, et al., 1988) with a high

internal consistency (Cronbach's α=0.85 – 0.91) and test-retest reliability (*r*=0.72 – 0.85). Construct validity was confirmed by a significant negative correlation with depression (*r*=-0.25, p<.01) and a significant sex effect on the total score, indicating that women significantly had greater support than men (6.05 vs. 5.55, p<.001). Internal consistency of the MSPSS in this study was excellent for each domain (Cronbach's α=0.91 - 0.93) and the full scale (Cronbach's α=0.93).

Data analysis

Descriptive statistics and Pearson correlation coefficients were computed for the study variables using SPSS 22.0 for Windows (Armonk, NY: IBM Corp). Structural equation modeling (SEM) was conducted using AMOS 21.0 (Chicago: IBM Corp) to test model fit of the ESH.

Data preparation

Seven cases with incomplete or invalid data were first excluded. Missing data analysis was then conducted using SPSS. The results indicated that there were no variables with more than 5% missing values (0 – 3.4%) and that the pattern of missing data was random (i.e., MACR). Accordingly, single imputation with regression substitution was used to estimate the missing values. Prior to imputation of missing values, z-scores were first calculated to identify outliers for each variable. After the data were visually inspected for outliers (|Z|≥3) (Kline, 2015), nine cases were further excluded because of invalid data on physical

activity (e.g., doing activities over 24 hours a day). Variables with missing values were included into the regression model, including body height and weight, time spent in different domains of physical activity, and items scores for all other measures (i.e., K6, ADC, ECR-RS, MPSSS, and scales for self-concept). Taking into account the potential sex effect on the variables measured in this study (Li, et al., 2016), the missing values were imputed for males and females separately. The normality of variables was finally examined, and correlation/covariance matrix was prepared for the SEM analysis.

Structural equation modeling

SEM with maximum likelihood estimation was used to test the full ESH model, which consisted of three latent measurement models of secondary stressors with three indicators (i.e., general stress, avoidance and anxiety of global relationships), one latent factor for perceived social support with three indicators (i.e., perceived social support from family, friends, and a significant other), and a latent self-concept factor with three indicators (i.e., self-esteem, mastery, and self-competence), along with several path models indicating different mediating pathways. Model fit for the three measurement models were first examined. The overall model fit of the original ESH was then reviewed (solid-line pathways in Figure 1). Model fit indices were examined and reported, and model fit was considered satisfactory if the following criteria were met: (1) $p>.05$ for x^2 statistics, (2) root mean square error (RMSEA) <.06, (3) non-normed fit index

(NNFI) >.90, (4) comparative fit index (CFI) >.90, and (5) goodness-of-fit index (GFI) >.90 (Bentler, 1983; Hu & Bentler, 1999).

Secondly, two direct pathways from physical activity and BMI to psychological distress were added separately and simultaneously (dash-line pathways in Figure 1), and model fit was re-examined. The comparison of a chi-square statistics and CFI between hierarchical models was used to identify if the extended ESH including pathways from physical activity and BMI to psychological distress was better than the original model. The statistically significant improvement in model fit is set at $p<.05$ for Δx^2 statistics and/or ΔCFI>.01 (Cheung & Rensvold, 2002).

Finally, independent-samples *t*-test and Chi-square statistics were conducted in SPSS to investigate the sex differences in all variables. Due to the small sample sizes in each group (56 males and 169 females), it was not possible to use multiple-sample analysis to examine the effect of sex on overall model fit or individual pathways (Kline, 2015). Given these sample size constraints, this part of the analysis employed a regression-based analysis to test the direct sex effect and its interaction with motor coordination (i.e. the ADC total score) on psychological distress. In order to control for multi-collinearity, the variables were first mean-centered, and then, the interaction of sex by motor coordination was created. In Model 1, sex was the only predictor of distress, and motor coordination and the interaction term were then added into the Model 2 and 3, respectively. Only in the presence of a significant sex effect, would the other

physical and psychosocial mediators be included in subsequent models. All significant statistical differences were set at α level <.05.

Results

Descriptive Statistics

The means and standard deviations of all variables are provided in Table 1. Pearson correlation coefficients showed that motor coordination was significantly associated with all psychosocial variables and psychological distress (all *p*'s <.05), indicating that poor motor coordination was related to higher psychological distress, higher general stress, poorer global relationships, lower perceived social support, and negative self-concept (i.e., self-esteem, mastery, and self-competence). Both physical activity and BMI were not significantly correlated (i.e., *p*>.05) with any of the other variables with the exception of the relationship between physical activity and general stress (r = .142, p<.05) and perceived social support from a significant other (r = -.139, p<.05). All psychosocial variables were significantly inter-related (all *p*'s<.01; See Table 1 for correlation coefficients).

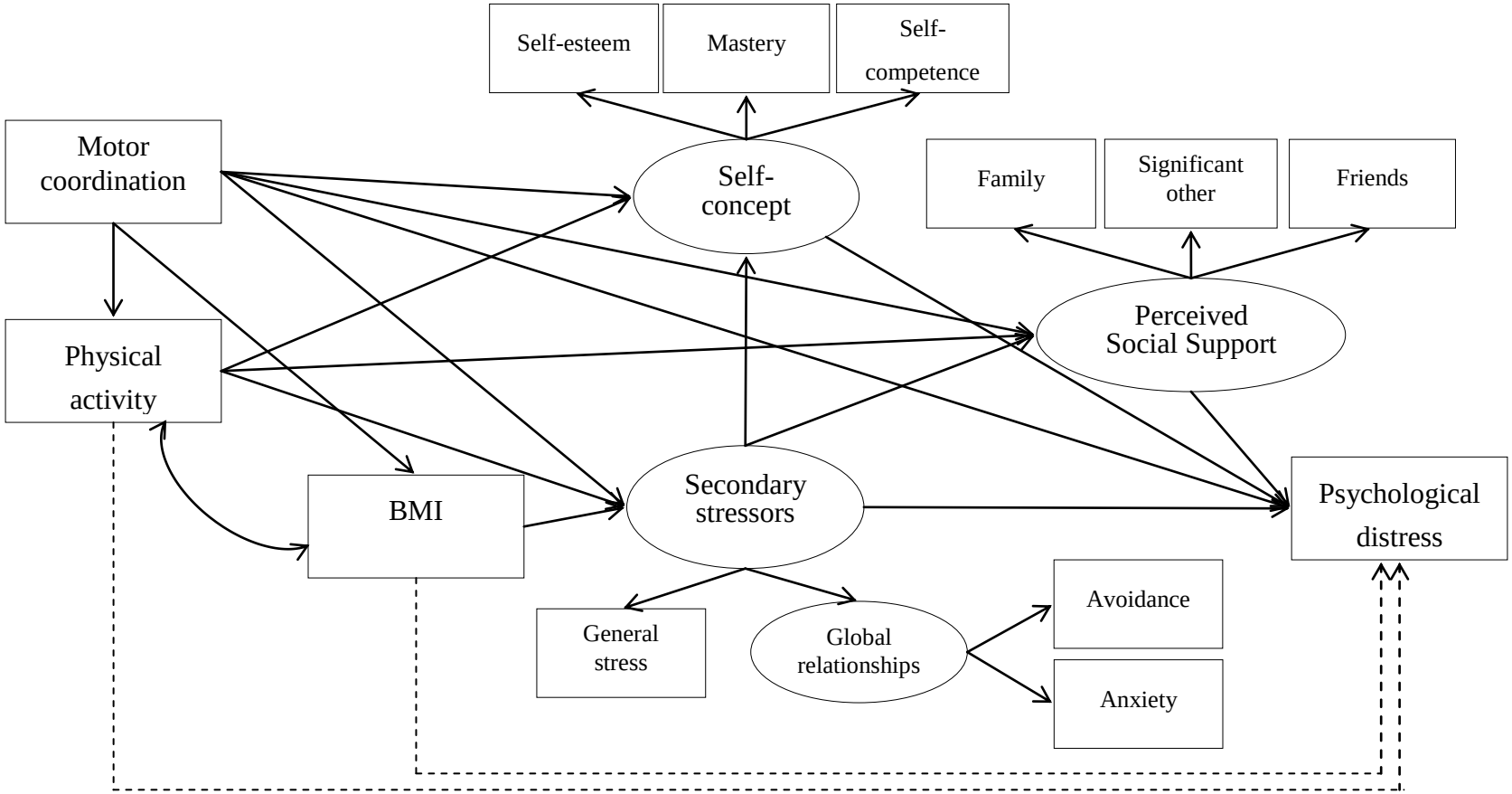


Figure 1. The original and extended ESH

Table 1. Descriptive statistics and correlation matrix

	Mean	SD	Correlation coefficients											
			1	2	3	4	5	6	7	8	9	10	11	12
1. ADC	62.0	13.2												
2. K6	8.8	4.9	.297											
3. IPAQ	39.8	39.0	-.030 [a]	-.037 [a]										
4. BMI	22.3	3.7	.005 [a]	-.005 [a]	.102 [a]									
5. General stress	3.5	2.3	.180	.472	.142	.047 [a]								
6. GR-avoidance	3.49	1.29	.193	.293	.048 [a]	.072 [a]	.216							
7. GR-anxiety	4.30	1.69	.283	.479	.024 [a]	.062 [a]	.304	.183						
8. PSS-SO	5.50	1.47	-.174	-.230	-.139	-.101 [a]	-.220	-.412	-.261					
9. PSS-Fam	5.24	1.44	-.215	-.256	-.071 [a]	-.095 [a]	-.333	-.348	-.296	.550				
10. PSS-Fri	5.48	1.24	-.114 [a]	-.328	-.040 [a]	-.054 [a]	-.214	-.505	-.277	.591	.483			
11. Self-esteem	21.5	3.4	-.238	-.458	-.010 [a]	-.002 [a]	-.190	-.352	-.370	.339	.351	.423		
12. Mastery	19.9	4.1	-.168	-.547	-.007 [a]	.028 [a]	-.346	-.221	-.402	.267	.292	.293	.241	
13. Self-competence	23.8	4.7	-.312	-.522	.076 [a]	.114 [a]	-.303	-.301	-.331	.211	.252	.320	.539	.444

[a] p>.05

ADC, Adult DCD/Dyspraxia Checklist; GR, Global Relationships; IPAQ, International Physical Activity Questionnaire; PSS, Perceived Social Support (SO, significant other; Fam, Family; Fri, Friends)

Structural equation modeling

Measurement Models for Latent Variables: Stress, Social Support and Self-Concept

The results of the normality test showed that neither severe skewness (|skewness|>3) nor severe kurtosis (|kurtosis|>10) was found for any of the variables (Kline, 2015), and thus no transformations were needed. The measurement models of perceived social support and self-concept were just-identified (df=0), with the saturated models showing perfect model fit. The model for secondary stressors was underidentified (df = -1). Therefore, in order to render this latent variable analyzable, the equality of constraint was imposed on the loadings from the latent factor to general stress (Kline, 2015). By doing so, this model became just-identified and saturated, which was appropriate for the SEM analysis.

Testing the ESH

The original model of the ESH was initially tested, and model fit indices did not show satisfactory model fit (x^2=117.86, p<.001; RMSEA=.077; NNFI=.864; CFI=.911; GFI=.929; Table 2). Therefore, modification index (MI) and standardized residuals (SR) were examined to guide the re-specification of the model. These indicators suggested two modifications: (1) correlating the error terms between perceived social support from friends and avoidance of global relationships (MI=9.48, SR=-2.90); (2) correlating errors between self-esteem and

mastery (MI=15.90, SR=-2.06) (Schermelleh-Engel, Moosbrugger, & Müller, 2003). Both suggested modifications were supported by previous studies showing a negative association between overall perceived social support and avoidance (Picardi et al., 2013; S. Wilson & Gore, 2013) and a positive association between self-esteem and a sense of mastery (Erol & Orth, 2011; Lipschitz-Elhawi & Itzhaky, 2005; Simoni, Huang, Goodry, & Montoya, 2006), and we therefore re-specified the model making these changes. The modified model showed improvements in model fit indices (x^2=83.24, p<.01; RMSEA=.056; NNFI=.927; CFI=.954; GFI=.947), indicating a better fit to the data when compared to the first model.

As shown in Figure 2, the significant relationship between motor coordination and psychological distress (unstandardized estimate=.112, S.E.=.024, p<.001) was mediated by secondary stressors and perceived social support, including a one-mediator pathway through secondary stressors and two sequential mediating pathways: the first through secondary stressors and perceived social support (motor coordination → secondary stressors → perceived social support → psychological distress); and the second through secondary stressors and self-concept (motor coordination → secondary stressors → self-concept → psychological distress).

Table 2. The goodness-of-fitness indices in all models

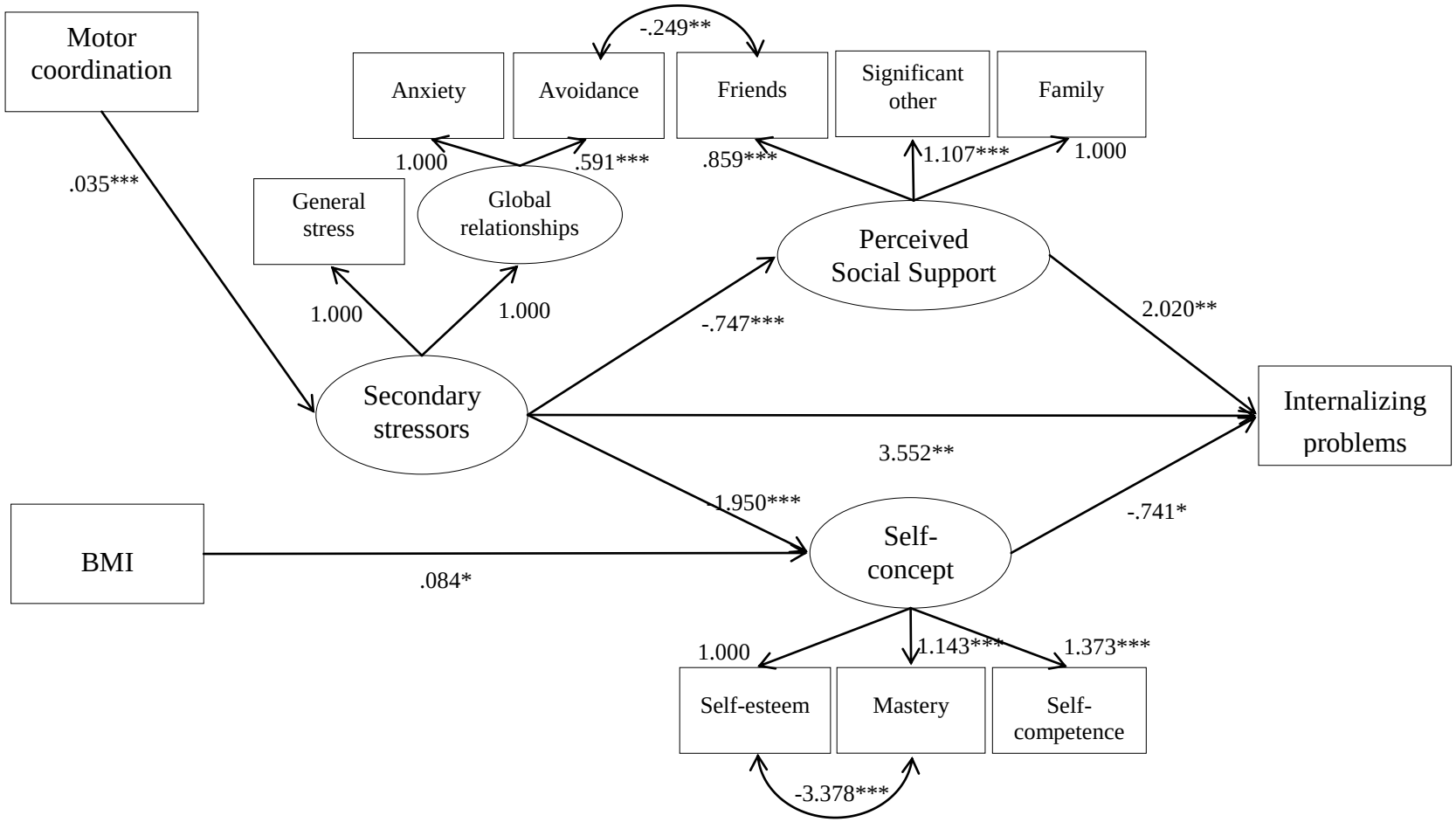
	x^2 (df, *p* value)	RMSEA	NNFI	CFI	GFI	Δx^2 (Δdf, *p*)	ΔCFI
Original Model	117.86 (51, $p<.001$)	0.077	0.864	0.911	0.929		
Modified Model	83.24 (49, $p<.01$)	0.056	0.927	0.954	0.947		
Extended Model 1	81.47 (48, $p<.01$)	0.056	0.927	0.955	0.948	1.77 (1, $p>.05$) [a]	-0.001[a]
Extended Model 2	82.89 (48, $p<.01$)	0.057	0.924	0.953	0.948	0.35 (1, $p>.05$) [a]	0.001[a]
Extended Model 3	81.01 (47, $p<.01$)	0.057	0.925	0.955	0.948	2.23 (2, $p>.05$) [a]	-0.001[a]

[a] Compared to Modified Model

Extended Model 1: modified model with the pathway from physical activity to internalizing problems

Extended Model 2: modified model with the pathway from BMI to internalizing problems

Extended Model 3: modified model with the pathways from physical activity and BMI to internalizing problem



*p<.05, ** p<.01, *** p<.001; only significant unstandardized estimates of pathways were reported.

Figure 2. The modified ESH

Testing of the Extended ESH

Three additional extended models (Extended Model 1, 2 and 3 in Table 3) were tested next. The differences in x^2 statistic and CFI were estimated and compared to the modified original model to identify if the extended models showed significant improvement in model fit over the model shown in Figure 2. The results showed that none of the extended models provided a better fit to the data than the modified original model (all *p*'s>.05 for Δx^2 statistics and all ΔCFI<.01), indicating that there were no direct effects of physical activity (Extended Model 1 in Table 3; unstandardized estimate=-.011, S.E.=.009, *p*=.21) or BMI (Extended Model 2 in Table 3; unstandardized estimate=-.057, S.E.=.097, *p* = .56) on psychological distress.

Sex effect and interactions

Significant sex differences were only found for physical activity, BMI, and the anxious domain of global relationships (Table 3): men were more physically active (*t*=-2.247, df=68.922, *p*<.05), had higher BMI (*t*=-3.051, df=223, *p*<.01), and were less anxious regarding global relationships (*t*=2.046, df=223, *p*<.05), when compared to women. The results of the regression analyses showed that neither the main effect of sex (b=.146, β=.013, *p*=.842) nor the interaction of sex by motor coordination (b=.096, β=.104, *p*=.107) predicted psychological distress (Table 4). As a significant sex effect on physical activity, BMI and anxiety toward global relationships, these three variables were separately added into the

regression models and two- (with sex *or* ADC) and three-way (with sex *and* ADC) interactions were created to examine the effects on internalizing problems. Except for the sex by physical activity interaction (b<.001, β=-.201, *p*<.01), none of two- and three-way interactions significantly predicted internalizing problems in young adults. The significant interaction between sex and physical activity indicated that both females and males who were physically inactive had similar levels of psychological distress, whereas young males who participated in greater amount of physical activity reported fewer internalizing problems compared to young females (Figure 3).

Table 3. Sex differences in motor coordination, physical and psychosocial factors, and psychological distress (Mean±SD or n(%))

	Male (n=56)	**Female (n=169)**
ADC	61.79 ± 12.01	62.14 ± 13.56
K6	8.86 ± 5.35	8.77 ± 4.82
IPAQ (10^2 MET-min/wk)*	52.52 ± 53.08	35.64 ± 32.23
BMI**	23.56 ± 3.59	21.83 ± 3.70
General stress	3.52 ± 2.39	3.53 ± 2.22
GR-avoidance	3.62 ± 1.42	3.44 ± 1.25
GR-anxiety*	3.90 ± 1.86	4.43 ± 1.61
PSS-Significant other	5.32 ± 1.64	5.56 ± 1.40
PSS-Family	5.34 ± 1.35	5.21 ± 1.47
PSS-Friend	5.56 ± 1.03	5.45 ± 1.30
Self-esteem	21.93 ± 3.80	21.31 ± 3.31
Mastery	19.88 ± 4.48	19.95 ± 3.92
Self-competence	24.82 ± 5.73	23.52 ± 4.33

* p<.05, ** p<.01

ADC, Adult DCD/Dyspraxia Checklist; GR, global relationships; IPAQ, International Physical Activity Questionnaire, PSS, perceived social support

Table 4. Main effect of sex and the interaction with motor coordination on psychological distress (unstandardized coefficients (S.E.))

	Model 1	Model 2	Model 3
Sex	.088 (.764)	.127 (.731)	.146 (.729)
ADC		.112 (.024)***	.116 (.024)***
Sex by ADC			.096 (.059)
Constant	8.791 (.330)***	8.791 (.316)***	8.798 (.315)***
Adjusted R^2	-.004	.080	.087

*** p<.001
ADC, Adult DCD/Dyspraxia Checklist

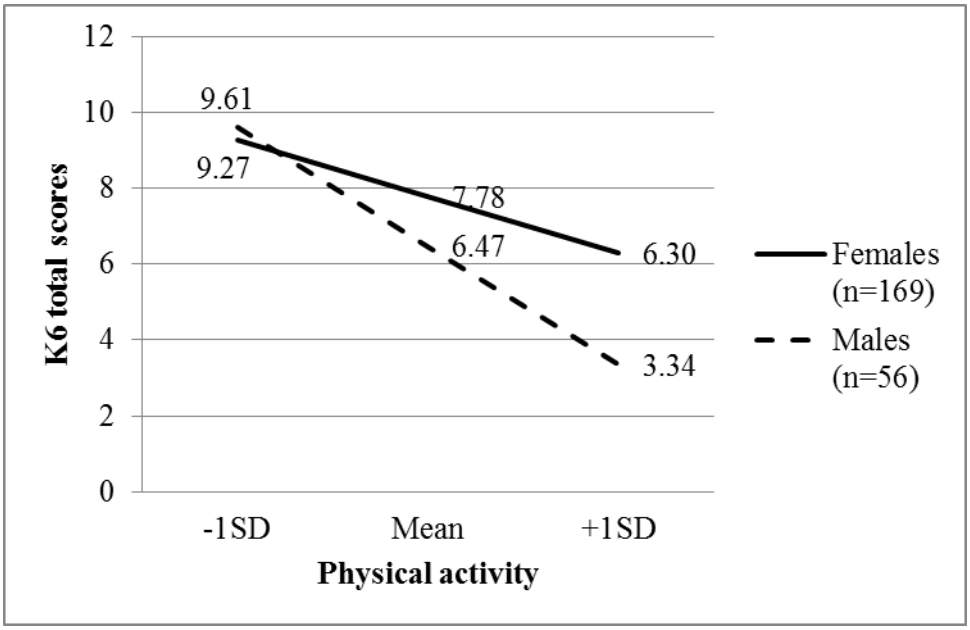


Figure 3. Sex by physical activity interaction on psychological distress

Discussion

This study is the most comprehensive examination to date investigating the ESH in any age group. The findings are promising and generally provide support the conceptual framework of the ESH. Poorer motor coordination is associated with increased psychological distress, high stress levels, poor global relationships, low perceived social support, and low self-concept (including self-esteem, mastery

and self-competence) in young adults. Moreover, stress, social support and self-concept mediate the relationship between motor coordination and psychological distress in this part of the life course.

Internalizing problems, such as increased symptoms of depression and anxiety, are evident in children with poor motor coordination, specifically DCD, across different age groups (Missiuna, et al., 2014; Piek, et al., 2008; Skinner & Piek, 2001). Consistent with previous studies of 12-16 year-old adolescents from community samples (Mancini, et al., 2016; Rigoli, et al., 2012; Viholainen, Aro, Purtsi, Tolvanen, & Cantell, 2014), this study demonstrated that poorer motor coordination were associated with higher psychological distress in young adults aged between the years of 17 and 23. There is a debate whether motor impairments and internalizing problems or psychological distress share the same etiology. Several twins studies have been conducted to investigate this issue further (Moruzzi et al., 2010; Pearsall-Jones, et al., 2011; Piek et al., 2007; Waszczuk, Leonard, Hill, Rowe, & Gregory, 2016). Among co-twins with a motor disorder, such as DCD, those with motor difficulties consistently reported higher levels of depressive and anxious symptomatology compared to their monozygotic co-twins without a motor disorder (Pearsall-Jones, et al., 2011; Piek, et al., 2007). These authors concluded that motor impairments in DCD and internalizing problems do not share the same etiology. Internalizing problems in twins with motor impairments were attributed to non-shared environmental factors, specifically motor difficulties in their daily living, rather than genetic or

shared environmental factors (Pearsall-Jones, et al., 2011; Piek, et al., 2007). To the contrary, two other studies using monozygotic and dizygotic twin pairs designs demonstrated that genetic influences contributed to the shared etiology of motor impairments and internalizing problems (Moruzzi, et al., 2010; Waszczuk, et al., 2016). Due to very limited evidence, the etiology of motor difficulties, including DCD and internalizing problems, warrants further investigation.

Although limited, previous research has shown that adults with poor motor coordination consistently reported having higher levels of depression and anxiety and perceived lower quality of life across several domains (e.g., physical health, work, and social relationships), and the potential mechanisms were speculated to be attributed to cerebellar dysfunction commonly shared by motor difficulties and internalizing problems or the cascading effect of motor difficulties on physical, psychosocial, and mental well-being (Hill & Brown, 2013; Waszczuk, et al., 2016). The results of this study indicate that the effect of motor coordination problems on psychological distress is also explained by differences in psychosocial well-being, including several mediating pathways that involve general stress, global relationships, perceived social support, and self-concept. Some of these mediating pathways have been identified in preschoolers, school-aged children, and adolescents in previous studies. For example, self-competence, specifically social competence, was found to mediate the relationship between poor motor abilities and higher emotional symptoms in preschool Australian children (A. Wilson, et al., 2013), whereas poor social relationships (e.g. peer

victimization or bullying), lower self-esteem, and social competence mediated the relationship between motor difficulties in DCD and internalizing problems in school-aged children (Campbell, Missiuna, & Vaillancourt, 2012; Lingam, et al., 2012). Self-concept has also consistently been found to mediate the relationship between motor coordination and mental health in community adolescent samples (Rigoli, et al., 2012; Viholainen, et al., 2014). It is worth noting that these previous studies only investigated a single mediator pathway, which might over-estimate the impact of self-worth on psychological problems.

In contrast to previous results in children and adolescents with motor difficulties who have been found to be more physically inactive and unfit compared to their coordinated peers (Cairney, Hay, Faught, & Hawes, 2005; Kwan, King-Dowling, Hay, Faught, & Cairney, 2016; Li, Wu, Cairney, & Hsieh, 2011), young adults with higher reported motor coordination problems in this study were not more likely to be physically inactive or have higher BMI relative to adults who reported no or fewer coordination problems. According to the skill-learning hypothesis (Wall, 2004), the gap in physical activity and fitness, particularly overweight/obesity, between children with and without motor difficulties should increase over time (Stodden et al., 2008). However, the gap in physical activity and weight status (i.e., BMI *herein*) does not mediate the relationship between motor problems and distress in this age group. Several possible explanations are might be operative.

First, overall low levels of physical activity in this age group may produce a floor effect (i.e., not enough variability in physical activity in both groups), which makes it difficult to detect a mediational effect. Indeed, about 40% of our participants (41.4% in females and 39.3% in males) fail to meet recommended guidelines for physical activity (i.e. 150 minutes/week of moderate to vigorous physical activity). Secondly, young adults with poor motor coordination may recognize their motor difficulties and, in turn, withdraw from structured social physical activities (e.g. team sports) (Kirby, et al., 2008), but choose instead individual activities that are less skill-demanding, competitive, and formal, such as exercising or working out in a gym, swimming, or jogging (Jarus, Lourie-Gelberg, Engel-Yeger, & Bart, 2011; Poulsen, Ziviani, & Cuskelly, 2008). In this sense, physical activity across levels of motor coordination reflects differences in the type of activity not overall participation.

With regard to BMI, when the adult cutoff criteria for weight status was applied (i.e., BMI≥25 for overweight and BMI≥30 for obesity) (Centers for Disease Control and Prevention, 2016), 70.2% of our participants (71.0% for females and 67.9% for males) had normal weight, whereas 14.7% (11.8% for females and 23.2% for males) and 4.0% (4.1% for females and 3.6% for males) were categorized into overweight and obesity, respectively. Despite a range of BMI found in our sample (a nearly normal distribution: skewness = 1.13 and kurtosis = 2.22), a relatively small sample size may potentially limit our ability to detect the impact of overweight/obesity on the relationship between motor

difficulties and psychological distress. Further research is needed to test if the mediation of BMI on this relationship would emerge by enlisting a larger sample size.

The effect of sex on internalizing problems, found in previous research (Wade, et al., 2002), was not replicated in this study. As this study recruited many fewer males than females, this discrepancy in sex distribution may have biased our results. Interestingly, regardless of motor coordination, young adults seem to benefit from participation in physical activity; young men in particular who were more physically active showed low levels of psychological distress. This is consistent with pervious research suggesting that physical activity or exercise can mitigate the symptoms of depression and anxiety, as well as stress (Pedersen & Saltin, 2015).

The results of this study should be considered in light of some limitations. The first concern focuses on motor coordination assessment, specifically the use of a self-report tool versus a standardized assessment. Even though a few standardized tests of motor coordination (e.g., Bruininks–Oseretsky Test of Motor Proficiency or Tufts Assessment of Motor Performance) could be used to assess motor performance in young adults, none of them can be considered as a gold standard to identify adults with DCD (Hands, et al., 2015). At present, the ADC is only measure currently available to assess motor coordination problems in adults. As this study could only recruit a community sample, we were limited in our ability to gather enough subjects who meet the criterion of DCD. As DCD is the

key, primary element of the ESH, further research may be able to enlist adults with a diagnosis of DCD in childhood to test the model and investigate if the underlying pathways may differ between the community and extreme samples. However, Cairney and colleagues (2013) acknowledge that the relationship between motor coordination problems and internalizing problems may not be limited to children or adults who score in the clinical range. Rather, there may be continuous relationship between motor ability and psychological distress, which is better captured by considering the full range of motor coordination, not just low end functioning at a clinical level. The results of this study support that position. The second limitation is the asymmetry of the sample with regard to sex. During the recruitment, young female undergraduate students were more inclined to respond the survey. Future research should recruit more men in order to test the effect of sex on model fit of the ESH, and ensure that the group size is large enough (n>100) to detect sex differences (Kline, 2015). Finally, the cross-sectional study design limits our ability to make statements regarding causality. Ideally, a prospective cohort study with a large sample size beginning in early childhood will provide more robust evidence regarding the potential long-term changes in the these relationships proposed within the ESH.

Conclusions

This study contributes to our understanding of the underlying mechanisms that might account for the effect of motor coordination problems on psychological distress in young adults. It also provides practical implications to guide interventions. Our results suggest that motor coordination problems may not only affect physical, but psychosocial health as well. For young adults with poor motor coordination, the provision of psychological counseling services, programs targeting reducing general stress or providing social support, should be considered alongside other interventions (e.g., physiotherapy), which are more commonly associated with treating motor problems. Such interventions may work to improve global relationships and self-concept, along with motor ability. Finally, as previous research indicates (Biddle & Asare, 2011), people with a range of motor skills may all benefit from physical activity or exercise to boost self-concept, reduce stress, and prevent mental health problems.

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CHAPTER 5:

GENERAL DISCUSSION

The overall objective of this dissertation was to test multiple pathways from the Environmental Stress Hypothesis (ESH) and in doing so, examine some of the underlying mechanisms linking DCD to internalizing problems from a developmental perspective. Results from Study 1 affirm that the co-occurrence of motor difficulties (i.e., rDCD) and internalizing problems emerges in early childhood, as young as ages 4 and 5 years. However, this relationship is not mediated by physical activity or BMI, and sex does not affect the relationship between rDCD and internalizing problems in preschool children. As such, these particular mechanisms identified in the ESH do not seem to be relevant for this particular developmental stage. The association between motor difficulties (i.e., pDCD) and internalizing problems is also confirmed in school-aged children. However, findings from Study 2 show that this relationship is sequentially mediated by physical activity/BMI and global self-worth, and that the underlying mechanisms of internalizing problems differs between boys and girls. Study 3 extended the first two studies in two important ways; first, it included variables from all of the core domains identified in the ESH to test multiple hypothesized pathways. Second, we sampled subjects from early adulthood to provide yet another test of how developmental stage might influence the impact of motor coordination on mental health, and the potential mediating pathways that connect motor to internalizing symptoms. Results showed that poor motor coordination is associated with a series of psychosocial factors that further increase the risk of internalizing problems. In this chapter, findings from all three studies are

synthesized to highlight the theoretical and practical implications, address the limitations of the studies, and provide recommendations for future research.

5.1 THEORETICAL IMPLICATIONS

Overall, the studies from this dissertation support the primary hypothesis of the ESH (Cairney, Rigoli, & Piek, 2013): motor difficulties, whether it is measured based on clinical thresholds or continuously, are associated with internalizing problems from early childhood to early adulthood. This dissertation also lends support to the existing framework and emphasizes the importance of the mediating effect of psychosocial factors on the relationship between motor difficulties and internalizing problems in school-aged children and young adults. The model's applicability to identify mechanisms in early childhood, however, is uncertain.

Even though previous longitudinal studies suggested that motor impairments may precede the onset of internalizing problems (Piek, Barrett, Smith, Rigoli, & Gasson, 2010; Sigurdsson, Van Os, & Fombonne, 2002), the findings of this dissertation highlight that motor difficulties and internalizing problems co-occur across three developmental stages from early childhood, through adolescence, to young adulthood. These findings suggest that the ESH may be also applicable to young adults with poor motor coordination or previously diagnosed DCD (Gagnon-Roy, Jasmin, & Camden, 2016; Hill & Brown, 2013; Kirby, Williams, Thomas, & Hill, 2013). Given that the association

is present in early childhood and persists across age groups, it is possible that both conditions share similar etiology, perhaps related to frontal dysfunction or very low birth weight, both of which have been found to be associated with motor and mental problems, respectively (Saridjan et al., 2014; Zwicker, Missiuna, Harris, & Boyd, 2011). Nevertheless, direct evidence of this connection remains to be tested.

A novel finding of this dissertation is that some of the meditating pathways identified in ESH may vary by developmental stage. For instance, physical activity and BMI were found to be significant mediators in school-aged children (Study 2), but not in preschool children or young adults (Study 1 and 3). Numerous cross-sectional and longitudinal studies have consistently found that school-aged children and adolescents with DCD or poor motor coordination participate less in physical activity (Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2010; Kwan, King-Dowling, Hay, Faught, & Cairney, 2016; Poulsen, Ziviani, & Cuskelly, 2008), are at greater risk of overweight or obesity (Joshi et al., 2015; Zhu, Wu, & Cairney, 2011), and experience more internalizing problems (Missiuna et al., 2014; Rigoli, Piek, & Kane, 2012; Skinner & Piek, 2001). In typically developing children, physical inactivity (Biddle & Asare, 2011; Kremer et al., 2014; Stavrakakis, de Jonge, Ormel, & Oldehinkel, 2012) and higher BMI (Geoffroy, Li, & Power, 2014; E. Hoare, Skouteris, Fuller-Tyszkiewicz, Millar, & Allender, 2014) are also associated with poorer mental health status. Although the mediating effects of physical activity and BMI have not been previously examined on the relationship between DCD and internalizing

problems, overall, it is plausible given previous literature that physical inactivity or higher BMI increases the levels of internalizing problems (Cairney, et al., 2013).

Interestingly, preschool children at risk for DCD and young adults with poor motor coordination were not found to be less physically active or have higher BMI compared to their coordinated peers, and neither factors were found to mediate the relationship between motor difficulties and internalizing problems (Study 1 and 3). These findings were contrary to previous research, indicating that the greater risks of physical inactivity and overweight/obesity were also found in young children (Kambas et al., 2012; Nervik, Martin, Rundquist, & Cleland, 2011; Williams et al., 2008) and adults (Gagnon-Roy, et al., 2016) with DCD or low motor competence; both physical inactivity and unhealthy weight could possibly emerge in preschool children with DCD as young as ages of 3 years and track into adulthood at the ages between 20 and 60 years. Different explanations are proposed here for this discrepancy at each developmental stage. As noted by activity-deficit and skill-learning gap hypotheses (Bar-Or, 1983; Wall, 2004), the differences in physical activity and BMI may be smaller between children with and without motor difficulties during early years because the motor skills demands of active free play or games is low. Because motor skill is not a barrier to participation, children with low motor competence may be just as active, and therefore have healthy weight, as typically developing children. Previous studies have shown that compared to typically developing peers, preschool children with

DCD or low motor competence had similar participation intensity and diversity (Bart, Jarus, Erez, & Rosenberg, 2011), and that BMI did not differ between groups (Hands, 2008; Schott, Alof, Hultsch, & Meermann, 2007). The results of this dissertation are consistent with this body of work.

It is not at all clear however that the skill demands hypothesis is applicable to young adults. Based on limited evidence (Cantell, Crawford, & Tish Doyle-Baker, 2008; Kirby, Sugden, Beveridge, & Edwards, 2008), it is suggested that adults with motor difficulties may engage less in team games or sports and develop poor physical fitness, such as higher BMI or poor muscular fitness. An alternative explanation may be linked with greater discretionary choice in adulthood: young adults with poor motor coordination may still participate in physical activity, but choose less organized activities or sports commensurate with their levels of motoric abilities (Gagnon-Roy, et al., 2016). In other words, while play and physical activity in early childhood may be "low demand" with respect to motor skills, greater discretion in choice of activities in adulthood may be more a salient influence on participation. An examination of discretionary choice in adults at different levels of motor competence is an important avenue for further research.

The finding that sex/gender influences mediating pathways connecting motor coordination problems to internalizing problems in middle childhood/adolescent but not in other developmental periods also warrants some attention. Indeed, adolescence has previously been identified as a significant

developmental period in relation to sex differences in depression: it is during this developmental stage, for example, that the classic two to one ratio in prevalence of depression between females and males emerges (Cairney, 1998; Petersen et al., 1993; Wade, Cairney, & Pevalin, 2002). For instance, it is believed that sex/gender role socialization associated with biological changes of puberty in early adolescence is one of factors resulting in higher levels of anxiety or depression in girls (Carter, Silverman, & Jaccard, 2011; Petersen, et al., 1993). In addition, adolescent girls often adopt negative coping strategies, such as emotional-focused or ruminative strategies, which may be less effective for coping with depression (C. E. Li, DiGiuseppe, & Froh, 2006; Priess, Lindberg, & Hyde, 2009). Previous research also suggests that female adolescents have lower levels of self-perceptions of competence (e.g., physical appearance) and global self-worth, both of which may further posit deleterious effects on mental health (Cole et al., 2009). Therefore, the stresses associated with motor coordination problems may be experienced or reacted differently given the developmental changes (social, psychological and biological) that are occurring for girls. However, the small number of subjects in studies 1 and 3 limit our ability to conclude that sex/gender is only relevant in this specific developmental period. Further research with larger samples of males and females across different developmental stages is required.

One of the most important contributions to our understanding of the ESH is that self-concept is among the most consistent and strongest predictors of

internalizing problems (Study 2 and 3). Previous research has shown self-esteem to be strongly associated with anxious and depressed symptoms in community samples including subjects from 8 to 80 years of age (Sowislo & Orth, 2013). Our measure of global self-worth, which is conceptually similar to self-esteem, is the most commonly studied component of self-concept in children or adolescents with DCD based on the ESH (Cairney, et al., 2013). Our findings support previous studies in children with or without DCD, indicating that self-esteem mediates the relationship between poor motor coordination and internalizing problems in 7- to 16-year-old children and adolescents (Lingam et al., 2012; Rigoli, et al., 2012). Our finding is somewhat contrary however to a recent study in adults, in which physical self-worth, specifically pertaining to physical appearance and motor competence, did not mediate the relationship between motor coordination and internalizing problems, even though this relationship was mediated by the other psychosocial factor (i.e., perceived social support) (Rigoli et al., in press). The inconsistency could be due to the differences in participants' age and the measure of personal resources. For example, Rigoli, et al. (in press) recruited 18- to 30-year-old adults, whereas our participants were undergraduate students (17- to 23-year-old); furthermore, they only measured the domain-specific self-perception, whereas we measured global perceptions of self-worth (Rigoli, et al., in press). Therefore, it is recommended that further research could include older participants (older than the university ages) and investigate the role

of self-concept in the ESH to extend our understanding of the underlying mechanisms of internalizing problems in older adults.

Self-concept however also includes psychosocial resources such as mastery and self-competence (as were included in Study 3). Although our findings support that these two factors are significantly associated with both motor coordination and psychological distress, these particular psychosocial resources have not been previously studied in relation to motor coordination problems. Further research should include a broader array of psychosocial factors and examine the mediating influence of these factors across the lifespan. Importantly, even though our understanding regarding the role of self-concept is limited by using an existing database in early childhood, the non-significant mediation of physical activity and BMI, and the direct effect of motor difficulties on internalizing problems may suggest that psychosocial health may be more important to mediate this relationship and must be taken into account in early childhood as recommended by the ESH (Cairney, et al., 2013). Even though preschool children with DCD may not be less physically active than typically developing children, these uncoordinated young kids children may already develop negative attitudes, such as less enjoyment in both physical activity and social participation (Bart, et al., 2011). Furthermore, preschool children with poor motor coordination may also have poorer social skills, which may also mediate the relationship between poor motor coordination and internalizing problems (Wilson, Piek, & Kane, 2013). The possibility cannot be ruled out that perceived

social support or social competence, both of which are identified in the ESH (Cairney, et al., 2013), could also act as mediators on the relationship between DCD and internalizing problems in early childhood as social skills may be associated with their interpersonal relationships and the development of the perception of social support.

5.2 PRACTICAL IMPLICATIONS

The findings of this dissertation provide several practical implications for the prevention and management/treatment of internalizing problems in children and adults with motor coordination problems. Although preschool children with rDCD were not more physically inactive or have higher BMI compared to their coordinated peers, these children with motor difficulties may have already developed higher levels of internalizing problems. Given that the activity deficit and the high likelihood of overweight or obesity may emerge with age and further deteriorate global self-worth later in development, consistent with the results found in Study 2, it is strongly recommended that in addition to targeting improvement in motor skills, preschool children with DCD must be encouraged to regularly engage in physical activity (e.g., 180 minutes at any intensity a day) (Canadian Society for Exercise Physiology, 2013) and maintain healthy weight status (e.g., 5^{th} – 85^{th} percentile of BMI) (Centers for Disease Control and Prevention, 2016). Indeed, early childhood is particularly critical developmental stage to establish healthy behaviours and these habits could track into adolescence

and adulthood (Y. C. Li, Kwan, King-Dowling, & Cairney, 2015). By doing so, we would be able to buffer the adverse effect of poor physical health (physical inactivity and overweight/obesity) on internalizing problems in children with DCD.

Based on findings from Study 2 and 3, psychosocial factors should also be considered as targets for intervention. In particular, studies 2 and 3 provide us with distinct practical implications for potential interventions via the links between physical activity, body composition and perceptions of self. In school-aged children, motor difficulties have historically been the priority for intervention as motor problems may hinder them from participating in physical activity and developing physical fitness, including healthy body composition (Rivilis et al., 2011). Fortunately, a considerable number of studies have shown poor motor performance in children with DCD could be improved by practicing motor skills or through using compensating strategies (e.g., learning to use a keyboard instead of printing or writing) (Niemeijer, Smits-Engelsman, & Schoemaker, 2007; Piek et al., 2010; Polatajko et al., 2001; Smits-Engelsman et al., 2013). Better motor coordination would then reduce the barriers of regular participation in physical activity and subsequently help the maintenance of healthy weight status. Through participation in physical activity, children can continue to develop motor skills, while at the same time nurture social relations that are beneficial for the perceptions of athletic and social competence (Poulsen, Ziviani, & Cuskelly, 2006, 2007), both of which will promote global self-worth

(Piek, Dworcan, Barrett, & Coleman, 2000). Of course, this is predicted on participation in activities that involves meaningful and positive engagement with peers. Achieving or maintaining healthy weight status through activity can also influence the perception of physical appearance, which is one of the strongest predictors of global self-worth (Piek, et al., 2000; Rose, Larkin, & Berger, 1997; Skinner & Piek, 2001). The improvement in global self-worth through participation in physical activity and healthy weight control may reduce internalizing problems in school-aged children with motor difficulties.

Even though motor coordination problems may be improved by practicing or using compensatory strategies, motor impairments may still continue to hinder some children with severe motor difficulties (e.g., DCD) from participation in physical activities. As a result, activities need to be carefully selected and, if necessary, adapted. Otherwise, difficulties with completing motor tasks or participating in physical activities may conversely cause frustration or the sense of failure (Mandich, Polatajko, & Rodger, 2003; Rodger & Mandich, 2005), and deteriorate internalizing problems. Furthermore, family members, friends or classmates, and others (e.g., teachers or family doctors) in their lives need to be educated regarding DCD and to effectively support children, youth and adults with the condition. For example, developing reasonable expectations about the child's abilities is an important first step. The school-based interdisciplinary intervention, *Partnering for Change* delivered by occupational therapists who act as consultants to teachers within school settings, provides children with DCD with

additional intensive support by emphasizing relationship building with and knowledge translation to teachers, as well as sharing information with parents to facilitate performance of daily activities and enhance participation in families or classrooms (Missiuna et al., 2012). Advocates believe the program has the potential to reduce some of the negative psychosocial consequences associated with DCD, such as bullying or being teasing, which are also risk factors for internalizing problems (Campbell, Missiuna, & Vaillancourt, 2012; Lingam, et al., 2012; Piek, Barrett, Allen, Jones, & Louise, 2005).

It is worth noting that most of interventions or training programs for children with DCD are developed to mainly address their motor difficulties and improve their performance on activities of daily living (e.g. Cognitive Orientation to Daily Occupational Performance or skill acquisition program) (Farhat et al., 2016; Polatajko, et al., 2001). Even though their psychosocial health may be improved after interventions, this is often collateral to the main goals of the therapy. To date, only a few interventions integrate both motor and psychosocial components (e.g., *Animal Fun* Program) to address overall well-being (Piek, Straker, et al., 2010). Given the significant sequential mediation of physical health and global self-worth on the relationship between motor difficulties and internalizing problems (Study 2), the integrated, comprehensive, systematic intervention, such as the *Animal Fun* Program, which has been shown to successfully improve preschool children's motor performance and prosocial behaviours (Piek et al., 2015; Piek et al., 2013), could be more effective in

improving mental health by simultaneously focusing on motor skills, activity participation, social interactions, and positive self-concept.

Findings from Study 3 also have implications for practice in young adults. One implication pertains to mental health services offered at universities. Unlike school-aged children with DCD, physical activity and the maintenance of healthy weight may not be ideal approaches that are beneficial for the improvements in self-concept and the prevention of internalizing problems in undergraduate students. Alternatively, in addition to the programs targeting motor difficulties, mental wellness services (individual consultation or supporting group) for those with poor motor coordination may provide support to cope with feelings of distress. Furthermore, numerous types of university support, such as extra examination time or additional tutorials (Kirby, et al., 2008), could be also beneficial for emerging adults with poor motor coordination to relieve their distress and improve the quality of student life, as well as other life domains (e.g. physical health, work, and household) (Hill, Brown, & Sorgardt, 2011).

Last but not least, beyond the personal, parental, and university levels, the government should also make efforts to prevent internalizing problems in children and youths with motor difficulties. A recent study has demonstrated that the rates of emergency department visits and hospitalizations for anxiety and mood/affective disorder in the 10- to 24-year-old population, the ages of who overlap those of our participants in Study 2 and 3, significantly increase over time (Gandhi et al., 2016). Therefore, ignoring depression and anxiety in those

children and youths with DCD is bound to lead to further stresses and strains on medical services. Taken together, the government should support policies (e.g., "*right care, right time, right place*") to create a positive environment, including the community-based mental health services for this uncoordinated population (Gandhi, et al., 2016).

5.3 LIMITATIONS

This dissertation has shed light on the importance of the underlying mechanisms of internalizing problems in the DCD population from early childhood to early adulthood, and highlighted the critical roles of physical and psychosocial well-being in the ESH. However, there are some limitations needed to be addressed.

The first limitation of this dissertation concerns the cross-sectional design of all three studies. As noted by the title of this dissertation, one of main purposes was to test the ESH from the "*developmental*" perspective. The developmental trajectories of several factors in the ESH could change in various ways across the life span, necessitating longitudinal study. For example, physical activity increases with age in early childhood, but gradually decreases while children transition into primary school (Y. C. Li, et al., 2015; Sallis, 1993). Furthermore, support from peers becomes increasingly important relative to family support during childhood and adolescence (Cheng & Chan, 2004; Coventry, Gillespie, Heath, & Martin, 2004). Global self-worth also shows an altered developmental

trajectory which increases during childhood, decreases in adolescence, and then increases again from late adolescence to adulthood (Bleidorn et al., 2016; Robins, Trzesniewski, Tracy, Gosling, & Potter, 2002). Therefore, a longitudinal study design is required to take these dynamic relationships into account and in doing so, assist us in better understanding how the ESH may influence mental health over time. According to the life course perspective (Avison, 2010), in order to understand trajectories of mental health problems, a number of life course experiences, such as school transitions or transitions to the labour force, have to be identified and tracked from childhood as potential vulnerable periods. A long-term follow-up study will allow us to identify the trajectories of risk and protective factors on internalizing problems in the DCD population.

Of course, this would require tracking the same individuals over long periods of time, which will be costly. To date, the longest follow-up period in studies of DCD with large enough numbers to examine multiple risk and protective factors is five years from middle childhood to early adolescence (i.e., PHAST study (used in Study 2) (Cairney, 2015)). Unfortunately, this data source does not allow for a comprehensive examination of the ESH over time given that psychosocial distress was only introduced later in the study. More longitudinal research to enhance our understanding of the potential causality of internalizing problems based on the ESH is required.

Second, based on the evidence from Study 2 and 3, psychosocial factors, including self-concept and perceived social support, were found to play important

roles in mediating the relationship between motor difficulties and internalizing problems. However, because it is not possible to accurately measure these psychosocial variables in preschool children, owing to the cognitive abilities of children with age, Study 1 could not examine the potential mediating effects of these factors. In fact, unlike motor performance, physical health, or behavioural problems that could be observed and objectively measured (Bart, et al., 2011; Kennedy-Behr, Rodger, & Mickan, 2013; King-Dowling, Missiuna, Rodriguez, Greenway, & Cairney, 2015; Pless, Carlsson, Sundelin, & Persson, 2002), psychological and emotional factors have not been well examined in preschool children at risk for DCD, and most of time, we rely on the proxy-report questionnaire to obtain information (Bart, et al., 2011; Piek, Bradbury, Elsley, & Tate, 2008). Hence, our understanding is still limited in terms of psychosocial well-being in preschool children at risk for DCD compared to typically developing children. It is worth noting however that it is not completely impossible to measure preschoolers' psychosocial well-being. By choosing proper measures, ones that use clear verbal instructions and pictures to guide testing, such as Perceived Efficacy and Goal Setting System (Missiuna, Pollock, Law, Walter, & Cavey, 2006), we may be capable of measuring some psychosocial constructs such as self-efficacy. However, even these measures have age limits (e.g. 5 years of age and older). For very young preschoolers, it is not yet possible to accurately assess psychosocial well-being. Future research has to prioritize and

validate appropriate measures of psychosocial status in preschool children and include them into the investigation of the relationships in the ESH.

The measurement of physical activity may be considered another limitation in this dissertation. Even though subjective measures have been shown to be reliable and valid to estimate physical activity levels in school-aged children (Study 2) and young adults (Study 3), and useful for obtaining contextual information concerning participation (Dollman et al., 2009), objectively-measured (e.g., accelerometers) physical activity (Study 1) can provide more accurate estimates of time spent in physical activity at various intensities while reducing recall bias associated with subjective measures (Trost, 2001; Ward, Evenson, Vaughn, Brown Roders, & Trioano, 2005). However, because our measures of physical activity were not the same across all studies, direct comparisons are not possible. Therefore, in future studies, both objective and subjective measures of physical activity are recommended to enhance our understanding of the amount of time spent in the different intensities and to understand the context of physical activity (e.g., sport participation versus walking to school).

The final limitation relates to the examination of the sex effect on the relationships in the ESH. As noted previously, due to relatively small sample sizes in each sex group, especially in studies 1 and 3, we were unable to adequately test the sex effect on the mediating pathways in the ESH. Nevertheless, we did find significant sex effects on physical activity across all three studies and on other variables, such as motor coordination (Study 1 and 3), BMI (Study 3), and global

self-worth (Study 2). Consistent with other studies, we also found a sex effect on physical activity and weight status in children with DCD (Cairney, et al., 2010; Cairney, Kwan, Hay, & Faught, 2012; Lifshitz et al., 2014). Nevertheless, further research with larger samples of boys and girls across different age ranges is required to more robustly examine the effect of sex on major pathways in the ESH. Analytically, use of structural equation modeling or path analyses is preferable in future work, as this will allow us to test multiple pathways that may be influenced by sex at the same time.

5.4 FUTURE DIRECTIONS

Although the ESH is comprehensive, there are other constructs not included in the model that might be useful to explore in future work. For example, as noted in the introduction chapter, the ESH is based on Pearlin's Stress Process model, where coping strategy is identified as a crucial buffering effect on the adverse effect of stress on internalizing problems (Pearlin, 1989; Pearlin, Menaghan, Lieberman, & Mullan, 1981). However, the importance of this moderator is not considered in the ESH (Cairney, et al., 2013). In fact, there is no study investigating the impact of coping strategies on internalizing problems in children with DCD. As coping resources and strategies are known to reduce the symptoms of anxiety and depression (Thoits, 1995), further research should investigate if differences in coping styles (e.g., problem-focused or emotion-

focused strategies) would protect or deteriorate internalizing problems in children or adults with motor difficulties.

It is also important to acknowledge that, beyond the contributing factors to internalizing problems depicted in the ESH, many prenatal and perinatal risk factors could simultaneously lead to poor motor coordination and elevated levels of internalizing problems. As previously discussed in Study 1, very low birth weight has been found to predict both DCD and internalizing problems (Bohnert & Breslau, 2008; Zwicker et al., 2013). Further research should investigate whether the risk of co-morbid DCD and internalizing problems are increased in children born pre-term.

Another question that has not been answered is the possibility of the intergenerational transmission of internalizing problems in families with children with DCD (Avison, 2014). Emerging evidence has indicated that parental mental illness exposes their offspring to elevated risk of mental health problems, including depression and anxiety (Beesdo, Knappe, & Pine, 2009; Bogels & Brechman-Toussaint, 2006; Parker & Roy, 2001). Even though an increasing number of studies have been conducted to investigate internalizing problems in children with DCD (Mancini, Rigoli, Cairney, Roberts, & Piek, 2016), mental health problems of their parents have been not examined, nor as the bi-directional relationships between parental and childhood internalizing problems. Given that the involvement of parents is crucial for the success of interventions, and that parents of children with DCD who have increased symptoms of internalizing

problems may also be more likely to be anxious and depressed, future research may need to develop family-centered interventions of internalizing problems for children with DCD by taking into account both parental and childhood mental health problems.

Further research could also examine other biological markers which have been linked to internalizing problem. For example, cortisol levels have been shown to be significantly higher in individuals with anxious and depressed symptoms (Tsigos & Chrousos, 2002). Because DCD is a chronic, ongoing stressor (Cairney, et al., 2013; Cairney & Veldhuizen, 2013), it is highly possible that the early life stressor of DCD, if not treated, may be linked to the dysfunction of hypothalamic-pituitary-adrenal axis, which in turn has been related to depression and obesity (Tofoli, Baes, Martins, & Juruena, 2011; Tsigos & Chrousos, 2002). Hence, an investigation of cortisol, which is the final effector of the hypothalamic-pituitary-adrenal axis, should be explored to assess physiological responses.

Last but definitely not least, we should bear in mind that DCD is a heterogeneous condition, which means motor impairments vary tremendously across individuals with the condition (Cermak & Larkin, 2002; Lord & Hulme, 1987). Some children may specifically have poor gross motor or poor balance (Dewey & Kaplan, 1994; Green, Chambers, & Sugden, 2008; D. Hoare, 1994; Macnab, Miller, & Polatajko, 2001), while others suffer primarily from poor manipulation or handwriting skills (Poulsen, Johnson, & Ziviani, 2011; Wright &

Sugden, 1996). We do not as yet know whether children with DCD, whose catching skills and/or balance are less affected, are less likely to develop internalizing problems because they may show fewer difficulties with participation in free play or organized activities that more demand gross motor skills. As far as the mediation of physical activity is concerned at school ages, the heterogeneity of DCD could impact the underlying mechanisms of internalizing problems. In other words, the pathways included in the ESH may vary across different subtypes of DCD. In addition, the severity of motor impairments could also impact internalizing problems in children, youth and adults with DCD. The findings of Study 3 suggest that poor motor coordination is linearly associated with more internalizing problems, and therefore, it may be reasonable to hypothesize that the DCD children with more severe motor impairments (i.e., at or below 5^{th} percentile) may experience much more serious mental illness than those with moderate DCD (i.e., 6^{th} – 15^{th} percentile). It is also worth noting that children with moderate DCD may grow out of motor impairments or develop their own strategies to compensate motor difficulties (Cantell, Smyth, & Ahonen, 1994; Pless, et al., 2002). Therefore, in these children, DCD could potentially lead to less negative and serious long-term impact on their physical and mental health.

Collectively, although the findings of this dissertation provided up-to-date evidence to support the ESH at different developmental stages and made several important theoretical and practical contributions to existing research on the mechanisms of internalizing problems in children and young adults with motor

difficulties, there are still many issues that have not been addressed. We are awaiting more research to fill these gaps in knowledge.

5.5 CONCLUSIONS

Most investigations of internalizing problems in children with DCD have not been guided by a theoretical framework. Based on the ESH (Cairney, et al., 2013), we are now able to better understand the potential underlying mechanisms of internalizing problems in children with DCD in a more systematical, theoretical way. The research findings from this dissertation provide support for the ESH and have made critical theoretical advancements indicating the ESH is dynamic, in which the underlying pathways may differ by age and sex.

Overall, this dissertation highlights the co-existence of DCD (or poor motor coordination) and internalizing problems across three developmental periods. The mediating role of self-concept has been found to be paramount in the ESH. The impacts of physical activity and weight status (i.e., BMI) vary between ages: both have been found to be parts of sequential mediating pathways from DCD to internalizing problems in school-aged children, whereas they seem not to explain the difference in internalizing problems between younger children and emerging adults with and without motor difficulties.

Moreover, findings from this dissertation accentuate the between-age difference in the underlying pathways connecting DCD and internalizing problems in spite of the fact that individuals with motor difficulties at all ages are

at greater risk for internalizing problems. Collectively, these findings particularly inform the importance that there is not a single intervention that will be suitable for all age group with motor difficulties. Interventions should be flexible and modified according to the sex and age.

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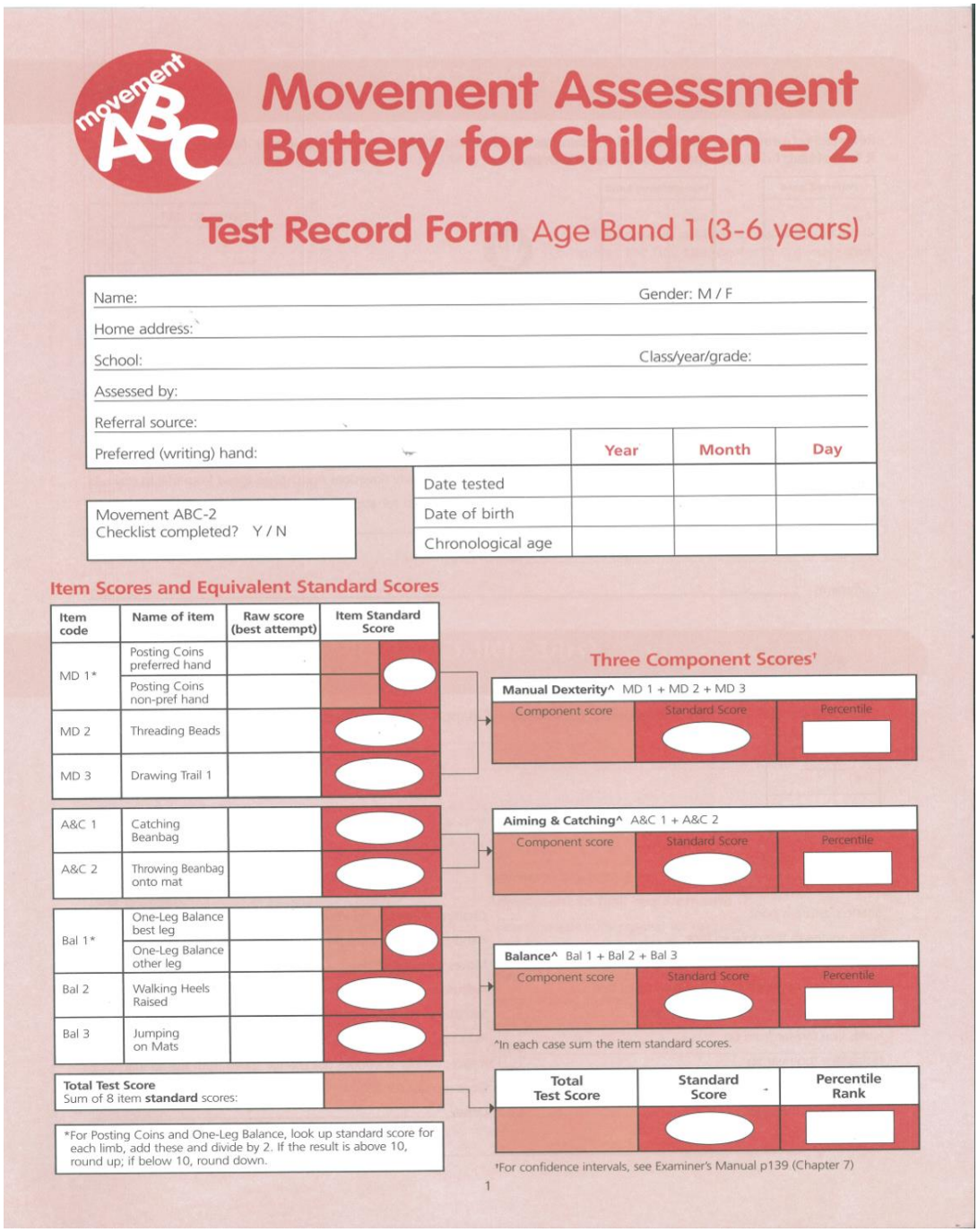
APPENDIX A: STUDY 1 MATERIALS

A.1 Movement Assessment Battery for Children – Second Edition

A.2 Child Behavior Checklist – Internalizing problems

Appendix A.1 Movement Assessment Battery for Children – Second Edition



Movement Assessment Battery for Children – 2

Test Record Form Age Band 1 (3-6 years)

Name: Gender: M / F

Home address:

School: Class/year/grade:

Assessed by:

Referral source:

Preferred (writing) hand:

Movement ABC-2 Checklist completed? Y / N

	Year	Month	Day
Date tested			
Date of birth			
Chronological age			

Item Scores and Equivalent Standard Scores

Item code	Name of item	Raw score (best attempt)	Item Standard Score
MD 1*	Posting Coins preferred hand		
	Posting Coins non-pref hand		
MD 2	Threading Beads		
MD 3	Drawing Trail 1		
A&C 1	Catching Beanbag		
A&C 2	Throwing Beanbag onto mat		
Bal 1*	One-Leg Balance best leg		
	One-Leg Balance other leg		
Bal 2	Walking Heels Raised		
Bal 3	Jumping on Mats		

Total Test Score
Sum of 8 item **standard** scores:

*For Posting Coins and One-Leg Balance, look up standard score for each limb, add these and divide by 2. If the result is above 10, round up; if below 10, round down.

Three Component Scores†

Manual Dexterity^ MD 1 + MD 2 + MD 3

Component score	Standard Score	Percentile

Aiming & Catching^ A&C 1 + A&C 2

Component score	Standard Score	Percentile

Balance^ Bal 1 + Bal 2 + Bal 3

Component score	Standard Score	Percentile

^In each case sum the item standard scores.

Total Test Score	Standard Score	Percentile Rank

†For confidence intervals, see Examiner's Manual p139 (Chapter 7)

1

Appendix A.2 Child Behavior Checklist – Internalizing problems

Please print. Be sure to answer all items.

CHILD BEHAVIOR CHECKLIST FOR AGES 1½-5

For office use only ID#

CHILD'S FULL NAME: First Middle Last

CHILD'S GENDER ☐ Boy ☐ Girl

CHILD'S AGE

CHILD'S ETHNIC GROUP OR RACE

TODAY'S DATE Mo. ____ Day ____ Year _____

CHILD'S BIRTHDATE Mo. ____ Day ____ Year ____

Please fill out this form to reflect *your* view of the child's behavior even if other people might not agree. Feel free to write additional comments beside each item and in the space provided on page 2. ***Be sure to answer all items.***

PARENTS' USUAL TYPE OF WORK, even if not working now. *Please be specific — for example, auto mechanic, high school teacher, homemaker, laborer, lathe operator, shoe salesman, army sergeant.*

FATHER'S TYPE OF WORK _____

MOTHER'S TYPE OF WORK _____

THIS FORM FILLED OUT BY: (print your full name)

_____

Your relationship to child:

☐ Mother ☐ Father ☐ Other (specify):

Below is a list of items that describe children. For each item that describes the child ***now or within the past 2 months***, please circle the ***2*** if the item is ***very true or often true*** of the child. Circle the ***1*** if the item is ***somewhat or sometimes true*** of the child. If the item is ***not true*** of the child, circle the ***0***. Please answer all items as well as you can, even if some do not seem to apply to the child.

0 = Not True (as far as you know) 1 = Somewhat or Sometimes True 2 = Very True or Often True

0 1 2 1. Aches or pains (without medical cause; *do not* include stomach or headaches)
0 1 2 2. Acts too young for age
0 1 2 3. Afraid to try new things
0 1 2 4. Avoids looking others in the eye
0 1 2 5. Can't concentrate, can't pay attention for long
0 1 2 6. Can't sit still, restless, or hyperactive
0 1 2 7. Can't stand having things out of place
0 1 2 8. Can't stand waiting; wants everything now
0 1 2 9. Chews on things that aren't edible
0 1 2 10. Clings to adults or too dependent
0 1 2 11. Constantly seeks help
0 1 2 12. Constipated, doesn't move bowels (when not sick)
0 1 2 13. Cries a lot
0 1 2 14. Cruel to animals
0 1 2 15. Defiant
0 1 2 16. Demands must be met immediately
0 1 2 17. Destroys his/her own things
0 1 2 18. Destroys things belonging to his/her family or other children
0 1 2 19. Diarrhea or loose bowels (when not sick)
0 1 2 20. Disobedient
0 1 2 21. Disturbed by any change in routine
0 1 2 22. Doesn't want to sleep alone
0 1 2 23. Doesn't answer when people talk to him/her
0 1 2 24. Doesn't eat well (describe): _____
0 1 2 25. Doesn't get along with other children
0 1 2 26. Doesn't know how to have fun; acts like a little adult
0 1 2 27. Doesn't seem to feel guilty after misbehaving
0 1 2 28. Doesn't want to go out of home
0 1 2 29. Easily frustrated
0 1 2 30. Easily jealous
0 1 2 31. Eats or drinks things that are not food—*don't* include sweets (describe): _____
0 1 2 32. Fears certain animals, situations, or places (describe): _____
0 1 2 33. Feelings are easily hurt
0 1 2 34. Gets hurt a lot, accident-prone
0 1 2 35. Gets in many fights
0 1 2 36. Gets into everything
0 1 2 37. Gets too upset when separated from parents
0 1 2 38. Has trouble getting to sleep
0 1 2 39. Headaches (without medical cause)
0 1 2 40. Hits others
0 1 2 41. Holds his/her breath
0 1 2 42. Hurts animals or people without meaning to
0 1 2 43. Looks unhappy without good reason
0 1 2 44. Angry moods
0 1 2 45. Nausea, feels sick (without medical cause)
0 1 2 46. Nervous movements or twitching (describe): _____
0 1 2 47. Nervous, highstrung, or tense
0 1 2 48. Nightmares
0 1 2 49. Overeating
0 1 2 50. Overtired
0 1 2 51. Shows panic for no good reason
0 1 2 52. Painful bowel movements (without medical cause)
0 1 2 53. Physically attacks people
0 1 2 54. Picks nose, skin, or other parts of body (describe): _____

Be sure you answered all items. Then see other side.

Please print your answers. Be sure to answer all items.

0 = Not True (as far as you know) 1 = Somewhat or Sometimes True 2 = Very True or Often True

0 1 2 55. Plays with own sex parts too much
0 1 2 56. Poorly coordinated or clumsy
0 1 2 57. Problems with eyes (without medical cause) (describe): _____
0 1 2 58. Punishment doesn't change his/her behavior
0 1 2 59. Quickly shifts from one activity to another
0 1 2 60. Rashes or other skin problems (without medical cause)
0 1 2 61. Refuses to eat
0 1 2 62. Refuses to play active games
0 1 2 63. Repeatedly rocks head or body
0 1 2 64. Resists going to bed at night
0 1 2 65. Resists toilet training (describe): _____
0 1 2 66. Screams a lot
0 1 2 67. Seems unresponsive to affection
0 1 2 68. Self-conscious or easily embarrassed
0 1 2 69. Selfish or won't share
0 1 2 70. Shows little affection toward people
0 1 2 71. Shows little interest in things around him/her
0 1 2 72. Shows too little fear of getting hurt
0 1 2 73. Too shy or timid
0 1 2 74. Sleeps less than most kids during day and/or night (describe): _____
0 1 2 75. Smears or plays with bowel movements
0 1 2 76. Speech problem (describe): _____
0 1 2 77. Stares into space or seems preoccupied
0 1 2 78. Stomachaches or cramps (without medical cause)
0 1 2 79. Rapid shifts between sadness and excitement
0 1 2 80. Strange behavior (describe): _____
0 1 2 81. Stubborn, sullen, or irritable
0 1 2 82. Sudden changes in mood or feelings
0 1 2 83. Sulks a lot
0 1 2 84. Talks or cries out in sleep
0 1 2 85. Temper tantrums or hot temper
0 1 2 86. Too concerned with neatness or cleanliness
0 1 2 87. Too fearful or anxious
0 1 2 88. Uncooperative
0 1 2 89. Underactive, slow moving, or lacks energy
0 1 2 90. Unhappy, sad, or depressed
0 1 2 91. Unusually loud
0 1 2 92. Upset by new people or situations (describe): _____
0 1 2 93. Vomiting, throwing up (without medical cause)
0 1 2 94. Wakes up often at night
0 1 2 95. Wanders away
0 1 2 96. Wants a lot of attention
0 1 2 97. Whining
0 1 2 98. Withdrawn, doesn't get involved with others
0 1 2 99. Worries
0 1 2 100. Please write in any problems the child has that were not listed above.
0 1 2 _____
0 1 2 _____
0 1 2 _____

Please be sure you have answered all items. Underline any you are concerned about.

Does the child have any illness or disability (either physical or mental)? ☐No ☐Yes—Please describe:

What concerns you most about the child?

Please describe the best things about the child:

APPENDIX B: STUDY 2 MATERIALS

B.1 Participation Questionnaire

B.2 Harter's Self-Perception Profile – Global Self-Worth Subtest

B.3 K6 Scale

Appendix B.1 Participation Questionnaire

PARTICIPATION QUESTIONNAIRE

Name: _____ Age: _____ years

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

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

The following is a sample question to practice.

SAMPLE QUESTION

1. How often do you eat an apple?

Never	Once a month	Once a week	Once a day
θ	θ	θ	θ

SECTION 1: FREE TIME ACTIVITIES
This section asks questions about what you do during your free time. Some of the questions will be about recess, some about what you like to do after school, and others will be about what you do on weekends and holidays. Active games mean things like tag or skipping or playing catch.

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

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

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

Watch television	Talk with my friends	Play active games	Play video games	Do other things (Specify below)
θ	θ	θ	θ	_____

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

Watch television	Talk with my friends	Read books	Play active games	Do other things (Specify below)
θ	θ	θ	θ	_____

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

Watch television	Read	Play active games	Play video games	Talk with my friends	Do other things (Specify below)
θ	θ	θ	θ	θ	_____

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

1. _____ 2. _____ 3. _____

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

Never	Once a month	Once a week	Once a day	All the time
θ	θ	θ	θ	θ

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

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

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

Never	Once a month	Once a week	Once a day	All the time
θ	θ	θ	θ	θ

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

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

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

Never	Once a month	Once a week	Once a day	All the time
θ	θ	θ	θ	θ

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

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

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

Never	Once a month	Once a week	Once a day	All the time
θ	θ	θ	θ	θ

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

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

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

1. _____ 2. _____ 3. _____

15. How often do you watch television?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Very often	Often	Sometimes	Hardly ever	Never
θ	θ	θ	θ	θ

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

1. _____ 2. _____ 3. _____

24. How do you usually get to school?

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

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

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

26. How many older brothers do you have? _____

27. How many older sisters do you have? _____

28. How many younger brothers do you have? _____

29. How many younger sisters do you have? _____

SECTION 2: INTRAMURAL or HOUSE LEAGUE GAMES

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

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

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

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

Very often	Often	Sometimes	Hardly ever	Never
θ	θ	θ	θ	θ

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

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

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

35. How many of your friends play intramural games?

Most of them	A few of them	None of them
❑	❑	❑

SECTION 3: SCHOOL SPORTS TEAMS

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

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

0	1	2	3	4
θ	θ	θ	θ	θ

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

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

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

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

Very often	Often	Sometimes	Hardly ever	Never
θ	θ	θ	θ	θ

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

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

Most of them	A few of them	None of them
❑	❑	❑

SECTION 4: SPORTS TEAMS OUTSIDE OF SCHOOL

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

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

If you answered 0, go directly to SECTION 5)

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

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

Very often	Often	Sometimes	Hardly ever	Never
θ	θ	θ	θ	θ

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

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

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

Most of them	A few of them	None of them
❑	❑	❑

SECTION 5: SPORTS AND DANCE CLUBS

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

47. In the last year, how many DANCE clubs have you belonged to?

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

48. In the last year, how many SPORTS clubs did you belong to?

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

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

Very often	Often	Sometimes	Hardly ever	Never
θ	θ	θ	θ	θ

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

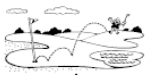
Very tired	Tired	A little tired	Not tired at all
❑	❑	❑	❑

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

Most of them	A few of them	None of them
❑	❑	❑

SECTION 6: SPORTS AND DANCE LESSONS

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



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

0	1	2	3	4	5 or more

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

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

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

0	1	2	3	4	5 or more
θ	θ	θ	θ	θ	θ

58A. How many of your friends take sport or dance lessons?

Most of them	A few of them	None of them
❑	❑	❑

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

Very often	Often	Sometimes	Hardly ever	Never
θ	θ	θ	θ	θ

SECTION 7: UNDERSTANDING YOUR BODY

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

59. I think I weigh _____ pounds.

60. I think I am _____ feet _____ inches tall.

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

Very underweight	Somewhat underweight	Just the right weight	Somewhat overweight	Very overweight
θ	θ	θ	θ	θ

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

Lose a lot of weight	Lose a little weight	Stay the same	Gain a little weight	Gain a lot of weight
θ	θ	θ	θ	θ

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

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

THANK YOU VERY MUCH FOR COMPLETING THE PARTICIPATION QUESTIONNAIRE! ☺

Appendix B.2 Harter's Self-Perception Profile

HARTER SCALE

Take your time and do the whole form carefully. If you have any questions just ask! If you think you are ready you can start now. BE SURE TO FILL IN BOTH SIDES OF EACH PAGE!

REALLY TRUE for me	SORT OF TRUE for me				SORT OF TRUE for me	REALLY TRUE for me
❑	❑	Some kids feel that they are very *good* at their school work.	**BUT**	Other kids *worry* about whether they can do the school worked assigned to them.	❑	❑
❑	❑	Some kids find it *hard* to make friends.	**BUT**	Other kids find it is pretty *easy* to make friends.	❑	❑
❑	❑	Some kids do *very well* at all kinds of sports.	**BUT**	Other kids *don't* feel that they are very good when it comes to sports.	❑	❑
❑	❑	Some kids are *happy* with the way they look.	**BUT**	Other kids are *not* happy with the way they look.	❑	❑
❑	❑	Some kids often do *not* like the way they behave.	**BUT**	Other kids usually *like* the way they behave.	❑	❑
❑	❑	Some kids are often *unhappy* with themselves.	**BUT**	Other kids are pretty *pleased* with themselves.	❑	❑
❑	❑	Some kids feel like they are just as *smart* as other kids their age.	**BUT**	Other kids aren't so sure and *wonder* if they are as smart.	❑	❑
❑	❑	Some kids have a lot of friends.	**BUT**	Other kids don't have very many friends.	❑	❑
❑	❑	Some kids wish they could be a lot better at sports.	**BUT**	Other kids feel they are good enough at sports.	❑	❑

REALLY TRUE for me	SORT OF TRUE for me				SORT OF TRUE for me	REALLY TRUE for me
❑	❑	Some kids are *happy* with their height and weight.	**BUT**	Other kids wish their height and weight were *different*.	❑	❑
❑	❑	Some kids usually do the *right* thing.	**BUT**	Other kids often *don't* do the right thing.	❑	❑
❑	❑	Some kids *don't* like the way they are leading their life.	**BUT**	Other kids *do* like the way they are leading their life.	❑	❑
❑	❑	Some kids are pretty *slow* in finishing their school work.	**BUT**	Other kids can do their school work *quickly*.	❑	❑
❑	❑	Some kids would like to have a lot more friends.	**BUT**	Other kids have as many friends as they want.	❑	❑
❑	❑	Some kids think they could do well at just about any new sports activity they haven't tried before.	**BUT**	Other kids are afraid they might *not* do well at sports they haven't ever tried.	❑	❑
❑	❑	Some kids wish their body was *different*.	**BUT**	Other kids *like* their body the way it is.	❑	❑
❑	❑	Some kids usually *act* the way they know they are *supposed* to.	**BUT**	Other kids often *don't* act the way they are supposed to.	❑	❑
❑	❑	Some kids are *happy* with themselves as a person.	**BUT**	Other kids are often *not* happy with themselves.	❑	❑
❑	❑	Some kids often *forget* what they learn.	**BUT**	Other kids can remember things *easily*.	❑	❑
❑	❑	Some kids are always doing things with *a lot* of kids.	**BUT**	Other kids usually do things by *themselves*.	❑	❑

REALLY TRUE for me	SORT OF TRUE for me				SORT OF TRUE for me	REALLY TRUE for me
❑	❑	Some kids feel that they are *better* than others their age at sports.	**BUT**	Other kids *don't* feel they can play as well.	❑	❑
❑	❑	Some kids wish their physical appearance (how they look) was *different*.	**BUT**	Other kids *like* their physical appearance the way it is.	❑	❑
❑	❑	Some kids usually get in *trouble* because of things they do.	**BUT**	Other kids usually *don't* do things that get them in trouble.	❑	❑
❑	❑	Some kids *like* the kind of person they are.	**BUT**	Other kids often wish they were someone else.	❑	❑
❑	❑	Some kids do *very well* at their class work.	**BUT**	Other kids *don't* do very well at their class work.	❑	❑
❑	❑	Some kids wish that more people their age liked them.	**BUT**	Other kids feel that most people their age *do* like them.	❑	❑
❑	❑	In games and sports, some kids usually *watch* instead of play.	**BUT**	Other kids usually *play* rather than just watch.	❑	❑
❑	❑	Some kids wish something about their face or hair looked *different*.	**BUT**	Other kids *like* their face and hair the way they are.	❑	❑
❑	❑	Some kids do things they know they *shouldn't* do.	**BUT**	Other kids *hardly* ever do things they know they shouldn't do.	❑	❑
❑	❑	Some kids are very *happy* being the way they are.	**BUT**	Other kids wish they were *different*.	❑	❑
❑	❑	Some kids have *trouble* figuring out the answer in school.	**BUT**	Other kids almost *always* can figure out the answer.	❑	❑

REALLY TRUE for me	SORT OF TRUE for me				SORT OF TRUE for me	REALLY TRUE for me
❑	❑	Some kids are *popular* with others their age.	**BUT**	Other kids are *not* very popular.	❑	❑
❑	❑	Some kids *don't* do well at new outdoor games.	**BUT**	Other kids are *good* at new games right away.	❑	❑
❑	❑	Some kids think that they are good looking.	**BUT**	Other kids think that they are not very good looking.	❑	❑
❑	❑	Some kids behave themselves very well.	**BUT**	Other kids often find it hard to behave themselves.	❑	❑
❑	❑	Some kids are not very happy with the way they do a lot of things.	**BUT**	Other kids think the way they do things is *fine*.	❑	❑

THANK YOU VERY MUCH FOR COMPLETING THE HARTER SCALE! ☺

Appendix B.3 K6 Scale

During the past 30 days, about how often did you feel…

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a. …nervous?	**1**	**2**	**3**	**4**	**5**
b. …hopeless?	**1**	**2**	**3**	**4**	**5**
c. …restless or fidgety?	**1**	**2**	**3**	**4**	**5**
d. …so depressed that nothing could cheer you up?	**1**	**2**	**3**	**4**	**5**
e. …that everything was an effort?	**1**	**2**	**3**	**4**	**5**
f. …worthless?	**1**	**2**	**3**	**4**	**5**

APPENDIX C: STUDY 3 MATERIALS

C.1 SMART Study – Online Survey

Appendix C.1 SMART Study – Online Survey

SMART: Stress and Motor Ability Relationship in Teenagers

Demographic and Health Survey

We ask that the following questions be answered by yourself. The questions are about your (1) basic information, (2) motor coordination, (3) physical activity, (4) stress and social relationships, (5) experience with social support, (6) perception about yourself, and (7) distress. It will take about **30 minutes** to complete all questionnaires. You can skip any question that you do not wish to answer.

The information will only be used for descriptive purpose. In other words, **NO** individual information will be reported or shared.

Please answer these questions about **YOURSELF** or based on **YOUR EXPERIENCE.**

This information will be kept completely confidential.

When you answer the questions in this survey,

PLEASE DO NOT TALK ABOUT YOUR ANSWERS WITH ANYONE ELSE,

and **ASK THE RESEARCHERS' FOR HELP IF YOU HAVE ANY QUESTIONS.**

Section 1. Learning about you

For researchers use only – Do not write this section

Entered by _____ Date: _____

Checked by _____ Date: _____

BASIC INFORMATION

Study ID: _____

Gender: ☐ Male ☐ Female ☐ Other Today's date (yy/mm/dd): _____/_____/_____

Date of Birth (yy/mm/dd): _____/_____/_____

Department: _____

Year of study (e.g. first year): _____

Current weight: _____ kg **OR** _____ lb

Current height: _____ cm **OR** _____ ft _____ in

HEALTH CONDITIONS

Has a health professional diagnosed you with any of the following conditions?

Condition

☐ Diabetes
☐ Heart condition or disease
☐ Epilepsy
☐ Cerebral palsy
☐ Kidney condition or disease
☐ Down syndrome
☐ Attention Deficit/Hyperactivity Disorder (ADHD or ADD)
☐ Autism Spectrum Disorder (ASD) or Asperger's Syndrome
☐ Pervasive Developmental Disorder (PDD)
☐ Developmental Coordination Disorder (DCD)
☐ Deafness/hearing loss
☐ Spina Bifida
☐ Learning Disability or Dyslexia
☐ Tourette Syndrome
☐ Muscular Dystrophy
☐ Hemiplegia
☐ Visual impairment
☐ Other long-term condition, please specify: _____
☐ None of the above (*Skip to Section 2*)

Please specify if you receive any treatment or intervention for the condition(s):

_____

Who diagnosed you? (e.g. family doctor, or psychiatrist) _____

Don't know ☐

When were you diagnosed? Please specify age (e.g. 7 year olds) or period (e.g. elementary school) _____ Don't know ☐

Section 2. Motor coordination

Please circle the number as appropriate.

Part I. As a child (about 4 to 12 year-old), did you: (please answer questions from what you can remember)				
	Never	**Sometimes**	**Frequently**	**Always**
1. Have difficulties with self-care tasks, such as tying shoelaces, fastening buttons and zips?	**1**	**2**	**3**	**4**
2. Have difficulty eating without getting dirty?	**1**	**2**	**3**	**4**
3. Have difficulty learning to ride a bike compared to your peers?	**1**	**2**	**3**	**4**
4. Have difficulties with playing team games, such as football, volleyball, catching or throwing balls accurately?	**1**	**2**	**3**	**4**
5. Have difficulty writing neatly (so others could read it)?	**1**	**2**	**3**	**4**
6. Have difficulty writing as fast as your peers?	**1**	**2**	**3**	**4**
7. Bump into objects or people, trip over things more than others?	**1**	**2**	**3**	**4**
8. Have difficulty playing a musical instrument (e.g. violin, recorder)?	**1**	**2**	**3**	**4**
9. Have difficulties with organizing/finding things in your room?	**1**	**2**	**3**	**4**
10. Have others comment about your lack of coordination or call you clumsy?	**1**	**2**	**3**	**4**

Part II. Do you currently have difficulties with the following items:				
	Never	**Sometimes**	**Frequently**	**Always**
1. Self-care tasks such as shaving or make up?	**1**	**2**	**3**	**4**
2. Eating with a knife and fork/spoon?	**1**	**2**	**3**	**4**
3. Hobbies that require good coordination?	**1**	**2**	**3**	**4**
4. Writing neatly when having to write fast?	**1**	**2**	**3**	**4**
5. Writing as fast as your peers?	**1**	**2**	**3**	**4**
6. Reading your own writing?	**1**	**2**	**3**	**4**
7. Copying things down without making mistakes?	**1**	**2**	**3**	**4**
8. Organizing/finding things in your room?	**1**	**2**	**3**	**4**
9. Finding your way around new buildings or places?	**1**	**2**	**3**	**4**
10. Have others called you disorganized?	**1**	**2**	**3**	**4**
11. Do you have difficulties sitting still or appearing fidgety?	**1**	**2**	**3**	**4**
12. Do you lose or leave behind possessions?	**1**	**2**	**3**	**4**
13. Would you say that you bump into things, spill or break things?	**1**	**2**	**3**	**4**
14. Are you slower than others getting up on the morning and getting to work or school?	**1**	**2**	**3**	**4**
15. Did it take you longer than others to learn to drive? (☐ I don't drive)	**1**	**2**	**3**	**4**
16. Do others find it difficult to read your writing?	**1**	**2**	**3**	**4**
17. Do you avoid hobbies that require good coordination?	**1**	**2**	**3**	**4**
18. Do you choose to spend your leisure time more on your own than with others?	**1**	**2**	**3**	**4**
19. Do you avoid team games/sports?	**1**	**2**	**3**	**4**
20. If you do play a sport, is it more likely to be on your own, e.g. going to the gym, than with others?	**1**	**2**	**3**	**4**
21. Do you/did you avoid going to clubs/dancing?	**1**	**2**	**3**	**4**
22. If you are a driver, do you have difficulty parking a car? (☐ I don't drive)	**1**	**2**	**3**	**4**
23. Do you have difficulty preparing a meal from scratch?	**1**	**2**	**3**	**4**

	Never	Sometimes	Frequently	Always
24. Do you have difficulty packing a suitcase to go away?	**1**	**2**	**3**	**4**
25. Do you have difficulty folding clothes to put them away neatly?	**1**	**2**	**3**	**4**
26. Do you have difficulty managing money?	**1**	**2**	**3**	**4**
27. Do you have difficulties with performing two things at the same time (e.g. driving and listening or taking a telephone call)?	**1**	**2**	**3**	**4**
28. Do you have difficulties with distance estimation (e.g. with regard to parking, passing through objects)?	**1**	**2**	**3**	**4**
29. Do you have difficulty planning ahead?	**1**	**2**	**3**	**4**
30. Do you feel you are losing attention in certain situations?	**1**	**2**	**3**	**4**

Section 3. Physical activity

The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about all the **vigorous** and **moderate** activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

*Note: **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal, such as running or aerobic exercise.*

***Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal, such as dancing or gardening.*

PART A: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do **NOT** include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

☐ *Yes*

☐ No → ***Skip to PART B: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

_____ **days per week**

☐ No vigorous job-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

_____ **hours per day**

AND

_____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

_____ **days per week**

☐ No moderate job-related physical activity → ***Skip to question 6***

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**

AND

_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking → ***Skip to PART B: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**

AND

_____ **minutes per day**

PART B: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

   _____ **days per week**

   ☐ No traveling in a motor vehicle → ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

   _____ **hours per day**
   AND
   _____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

    _____ **days per week**

    ☐ No bicycling from place to place → ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

    _____ **hours per day**
    AND
    _____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

    _____ **days per week**

    ☐ No walking from place to place → ***Skip to PART C***

13. How much time did you usually spend on one of those days **walking** from place to place?

    _____ **hours per day**

    AND

    _____ **minutes per day**

PART C: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

    _____ **days per week**

    ☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

    _____ **hours per day**

    AND

    _____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

    _____ **days per week**

    ☐ No moderate activity in garden or yard → ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

    _____ **hours per day**

    AND

    _____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

    _____ **days per week**

    ☐ No moderate activity inside home → ***Skip to PART D***

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

    _____ **hours per day**

    AND

    _____ **minutes per day**

PART D: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

    _____ **days per week**

    ☐ No walking in leisure time → ***Skip to question 22***

1. How much time did you usually spend on one of those days **walking** in your leisure time?

    _____ **hours per day**

    AND

    _____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

    _____ **days per week**

    ☐ No vigorous activity in leisure time → ***Skip to question 24***

2. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ hours per day
AND
_____ minutes per day

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ days per week

☐ No moderate activity in leisure time → ***Skip to PART E***

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?

_____ hours per day
AND
_____ minutes per day

PART E: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ hours per day
AND
_____ minutes per day

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ hours per day
AND
_____ minutes per day

Section 4. Stress and social relationships

Part A of the questionnaire deals with different kinds of stress related to various aspects of a person's physical, emotional and mental health. **Part B** asks about your experiences in relationships in general.

Please read each of the following statements and circle or tick the answer as appropriate.

Part A. General Stress

1. You are trying to take on too many things at once.	☐ True ☐ False
2. There is too much pressure on you to be like other people.	☐ True ☐ False
3. Too much is expected of you by others.	☐ True ☐ False
4. You don't have enough money to buy the things you need.	☐ True ☐ False
5. Your work around the home is not appreciated.	☐ True ☐ False
6. Your friends are a bad influence.	☐ True ☐ False
7. You would like to move but you cannot.	☐ True ☐ False
8. Your neighbourhood or community is too noisy or too polluted.	☐ True ☐ False
9. You have a parent, a child or partner who is in very bad health and may die.	☐ True ☐ False
10. Someone in your family has an alcohol or drug problem.	☐ True ☐ False
11. People are too critical of you or what you do.	☐ True ☐ False

Part B. Experiences in Close Relationships

Circle the "1" if you **Strongly Disagree**
Circle the "2" if you **Disagree**
Circle the "3" if you **Somewhat isagree**
Circle the "4" if you are **Neutral**
Circle the "5" if you **Somewhat Agree**
Circle the "6" if you **Agree**
Circle the "7" if you **Strongly Agree**

	Strongly Disagree → Strongly Agree						
1. It helps to turn to people in times of need.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2. I usually discuss my problems and concerns with others.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
3. I talk things over with people.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
4. I find it easy to depend on others.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
5. I don't feel comfortable opening up to others.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
6. I prefer not to show others how I feel deep down.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
7. I often worry that other people do not really care for me.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
8. I'm afraid that other people may abandon me.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
9. I worry that others won't care about me as much as I care about them.	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Section 5. Your experience with social support

We are interested in how you feel about the following statements. Read each statement carefully. Indicate how you feel about each statement (using the scale provided, **"1, Very Strongly Disagree" to "7, Very Strongly Agree"**).

Circle the "1" if you **Very Strongly Disagree**
Circle the "2" if you **Strongly Disagree**
Circle the "3" if you **Mildly Disagree**
Circle the "4" if you are **Neutral**
Circle the "5" if you **Mildly Agree**
Circle the "6" if you **Strongly Agree**
Circle the "7" if you **Very Strongly Agree**

About how many close friends and close relatives do you have (people you feel at ease with and can talk to about what is on your mind)? _____ (Please write in number of close friends and close relatives)

	Very Strongly Disagree →						**Very Strongly Agree**
1. There is a special person who is around when I am in need.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2. There is a special person with whom I can share my joys and sorrows.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
3. My family really tries to help me.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
4. I get the emotional help and support I need from my family.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
5. I have a special person who is a real source of comfort to me.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
6. My friends really try to help me.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
7. I can count on my friends when things go wrong.	**1**	**2**	**3**	**4**	**5**	**6**	**7**

	Very Strongly Disagree						**Very Strongly Agree**
8. I can talk about my problems with my family.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
9. I have friends with whom I can share my joys and sorrows.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
10. There is a special person in my life who cares about my feelings.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
11. My family is willing to help me make decisions.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
12. I can talk about my problems with my friends.	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Section 6. Your perception about yourself

Part A. Self-Esteem, self-competence, and mastery

The following questions ask about your self-esteem, self-competence, and mastery. Please read each statement that people might use to describe themselves and circle the number indicating if you **strongly agree=1, agree=2, neither agree nor disagree=3, disagree=4, or strongly disagree=5**.

	Strongly Agree → Strongly Disagree				
Self-Esteem					
1. You feel that you have a number of good qualities.	**1**	**2**	**3**	**4**	**5**
2. You feel that you're a person of worth at least equal to others.	**1**	**2**	**3**	**4**	**5**
3. You are able to do things as well as most other people.	**1**	**2**	**3**	**4**	**5**
4. You take a positive attitude toward yourself.	**1**	**2**	**3**	**4**	**5**
5. On the whole you are satisfied with yourself.	**1**	**2**	**3**	**4**	**5**
6. All in all, you're inclined to feel you're a failure.	**1**	**2**	**3**	**4**	**5**
Self-competence					
1. I am highly effective at the things I do.	**1**	**2**	**3**	**4**	**5**
2. I am almost always able to accomplish what I try for.	**1**	**2**	**3**	**4**	**5**
3. At times, I find it difficult to achieve the things that are important to me.	**1**	**2**	**3**	**4**	**5**
4. I sometimes deal poorly with challenges.	**1**	**2**	**3**	**4**	**5**
5. I perform very well at many things.	**1**	**2**	**3**	**4**	**5**
6. I sometimes fail to fulfill my goals.	**1**	**2**	**3**	**4**	**5**
7. I am very talented.	**1**	**2**	**3**	**4**	**5**
8. I wish I were more skillful in my activities.	**1**	**2**	**3**	**4**	**5**

	Strongly Agree → Strongly Disagree				
Mastery					
1. You have little control over the things that happen to you.	**1**	**2**	**3**	**4**	**5**
2. There is really no way you can solve some of the problems you have.	**1**	**2**	**3**	**4**	**5**
3. There is little you can do to change many of the important things in your life.	**1**	**2**	**3**	**4**	**5**
4. You often feel helpless in dealing with problems of life.	**1**	**2**	**3**	**4**	**5**
5. Sometimes you feel that you are being pushed around in life.	**1**	**2**	**3**	**4**	**5**
6. What happens to you in the future mostly depends on you.	**1**	**2**	**3**	**4**	**5**
7. You can do just about anything you really set your mind to.	**1**	**2**	**3**	**4**	**5**

Section 7. Distress

The following questions ask about how you have been feeling during **the past 30 days**. For each question, please circle the number that best describes how often you had this feeling.

1. During the past 30 days, about how often did you feel…

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
a. …nervous?	**1**	**2**	**3**	**4**	**5**
b. …hopeless?	**1**	**2**	**3**	**4**	**5**
c. …restless or fidgety?	**1**	**2**	**3**	**4**	**5**
d. …so depressed that nothing could cheer you up?	**1**	**2**	**3**	**4**	**5**
e. …that everything was an effort?	**1**	**2**	**3**	**4**	**5**
f. …worthless?	**1**	**2**	**3**	**4**	**5**

2. The previous six questions above (Question 1a to 1f) asked about feelings that might have occurred during the past 30 days. Taking them altogether, did these feelings occur **more often** in the past 30 days than is usual for you, **about the same** as usual, or **less often** than usual? (If you **never** have any of these feelings, circle response option "4".)

More often than usual			About the same as usual	Less often than usual		
A lot	**Some**	**A little**		**A little**	**Some**	**A lot**
1	**2**	**3**	**4**	**5**	**6**	**7**

The next few questions are about how these feelings may have affected you in the past 30 days. You need not answer these questions if you answered "None of the time" to **all** of the six questions about your feelings.

3. During the past 30 days, how many days out of 30 were you **totally unable** to work or carry out your normal activities because of these feelings? **_____ (Number of days)**

4. **Not counting the days you reported in response to Question 3**, how many days in the past 30 were you able to do only **half or less** of what you would normally have been able to do, because of these feelings?
   _____ (Number of days)

5. During the past 30 days, how many times did you see a doctor or other health professional about these feelings?
   _____ (Number of times)

6. During the past 30 days, how often have physical health problems been the main cause of these feelings?	**All of the time**	**Most of the time**	**Some of the time**	**A little of the time**	**None of the time**
	1	**2**	**3**	**4**	**5**

- The End -