MOVEMENT PERFORMANCE AND PHYSICAL ACTIVITY AMONG STUDENTS WITH LEARNING AND/OR MOVEMENT DIFFICULTIES

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Chantelle Rae Zimmer, candidate for the degree of Master of Science in Kinesiology & Health Studies**,** has presented a thesis titled, ***Movement Performance and Physical Activity among Students with Learning and/or Movement Difficulties,*** in an oral examination held on August 21, 2013. The following committee members have found the thesis acceptable in form and content, and that the candidate demonstrated satisfactory knowledge of the subject material.

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Abstract

Approximately 8% of school-aged children have difficulty learning in the classroom and 5 to 6% demonstrate difficulties performing movement skills in the gymnasium. Are these characteristics mutually exclusive or is there some level of functional complexity inherent within each of them? This thesis is comprised of three manuscripts that collectively examine the range of impairments during the performance of movement skills among students 7 to 10 years of age with academic difficulties (AD) and movement difficulties (MD). Understanding similarities and differences in motor impairment among these students will provide valuable knowledge related to the implications of participation in physical activity. The first manuscript compared underlying processes (motor and executive functioning abilities) thought to contribute to the performance of movement skills among students with AD and MD. Similar impairments were found for students with AD and MD on tasks within the *Movement Assessment Battery for Children* that required manual dexterity and balance, but not ball skills. Impairments in executive functioning were most apparent among students with AD who were 9 and 10 years of age according to the results of the *Barkley Deficits in Executive Functioning Scale*. The second manuscript aimed to investigate similarities of motor impairment with respect to the performance of fundamental movement skills and the range of impairments among students with AD and MD compared to their typically developing peers. Students with MD demonstrated significantly less proficient performance on locomotor (*PE-Metrics*) and object control skills (both *TGMD-2* and *PE-Metrics*) than students with AD and their typically developing peers. However, students with AD and typically developing peers did not demonstrate proficient performance of these fundamental movement skills either, even by the age of 10. Impairments in the performance of fundamental movement skills

are likely to impact students' participation in physical activity, placing them at greater risk for health consequences associated with inactivity. The purpose of the third manuscript was to examine levels of physical activity for each of the three groups and subsequently, the relationship between movement performance and physical activity levels. Students with MD were significantly less active than their same-aged peers, and spent less time in more physically demanding activities associated with moderate and moderate-vigorous physical activity (MVPA). The time spent in MVPA was most strongly correlated with students' performance for object control skills on the *TGMD-2*. It appears that students who engage in higher levels of physical activity tend to demonstrate more proficient movement skills than students who are predominantly inactive. Inactivity may be detrimental to students' ability to become proficient in a variety of fundamental movement skills. These findings therefore illustrate the need for school-based intervention to improve the (learning and) performance of fundamental movement skills among students in order to increase their participation in physical activity or rather, decrease the amount of time spent being inactive.

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CHAPTER 1: Introduction

Learning disorders (LD) have historically been identified relative to the presence of specific diagnostic criteria. However, not all children who demonstrate learning difficulties in various academic areas receive a diagnosis or the appropriate services. Many children who have difficulty learning in the classroom, reflected by poor academic performance, also have difficulty performing movement skills in the gymnasium (Westendorp, Hartman, Houwen, Smith, & Visscher, 2011). Many children with attention-deficit/hyperactivity disorder (ADHD) also experience difficulty in the realms of learning and movement (Kaplan, Wilson, Dewey, & Crawford, 1998). About 18 to 42% of children with LD (Barkley, 2006; Willcutt & Pennington, 2000) and up to 50% of children with developmental coordination disorder (DCD; Kadesjö, & Gillberg, 1999; Watemberg, Waiserberg, Zuk, & Lerman-Sagie, 2007) also meet diagnostic criteria for ADHD.

The presence of more than one of these disorders is referred to as comorbidity. This would suggest the characteristics within each of these diagnoses are mutually exclusive. Given the overlap among many of these characteristics, it would be plausible to think there may be some level of functional complexity inherent within this group of disorders (Miller, Mâsse, Shen, Schiariti, & Roxborough, 2013). Functional complexity is focused on the wider range of impairments that an individual may experience, including physiological impairments and activity limitations. Relying on the presence of diagnostic criteria alone may under describe the breadth of difficulties that children with LD and DCD demonstrate. For instance, speculations of comorbidity among the neurodevelopmental disorders (Wilson, 2005) make recognition of DCD and the differentiation between LD and DCD difficult. Although LD, DCD, and ADHD are often comorbid, they are still seen as being distinct and tend to be diagnosed separately (Kaplan, Crawford, Cantell, Kooistra, & Dewey, 2006). Therefore, associated features of these three diagnoses may be considered a distinct disorder in some cases and a symptom of another disorder in others.

1.1 Identification and Prevalence of Neurodevelopmental Disorders

The fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-V*; American Psychiatric Association [APA], 2013) has recently been released with fairly minimal changes to what are now referred to as "neurodevelopmental disorders," which includes specific learning disorder (SLD), DCD, and ADHD (see Table 1). These disorders originate during the developmental years, with the manifestation of associated behaviours occurring during formal years of schooling. It is uncommon for one of these diagnoses to be made prior to the age of 10 because of differing rates of development demonstrated among young children.

With respect to this group of neurodevelopmental disorders, the most notable changes made in the *DSM-V* concern the identification of children with SLD. Manifestations are no longer limited to a single academic area such as reading. A diagnosis now acknowledges that various deficits may impact any or all areas of academic achievement (Scanlon, 2013). A formal diagnosis is multi-disciplinary and requires a clinical review of a child's developmental, medical, educational, and family history, as well as reports of test scores, teacher observations, and response to academic interventions (APA, 2013). As such, these review criteria emphasize the importance of a contextualized assessment process that considers a child's opportunity to learn in addition

Table 1

DSM-V Diagnostic Criteria for the Neurodevelopmental Disorders (American Psychiatric Association, 2013)

Criterion	Specific Learning Disorder
A	History or current presentation of persistent difficulties in the acquisition of reading, writing, or arithmetic during formal years of schooling
B	Current academic skills must be well below the average range of scores in culturally and linguistically appropriate tests of reading, writing, or mathematics
C	The individual’s difficulties must not be better explained by developmental, neurological, sensory (vision or hearing), or motor disorders
D	Learning difficulties identified in Criterion A must significantly interfere with academic achievement, occupational performance, or activities of daily living that require these academic skills
	Developmental Coordination Disorder
A	Marked impairments in motor coordination
B	Impairments must significantly interfere with the performance of movement skills needed for academic achievement or activities of daily living
C	Coordination difficulties cannot be the result of another medical condition (e.g., cerebral palsy) or attributed to a pervasive developmental disorder (e.g., autism)
D	If cognitive impairment is present, the coordination difficulties must be in excess of those usually associated with mental retardation
	Attention-Deficit/Hyperactivity Disorder
A	Children must have at least 6 symptoms from either (or both) the inattention or hyperactivity and impulsivity group of criteria
B	Several inattentive or hyperactive-impulsive symptoms are evident prior to age 12
C	Some impairment from the symptoms is present in two or more settings
D	Evidence of significant impairment in social, academic, or occupational functioning
E	Autism spectrum disorder may be present since symptoms of both disorders co-occur, but ADHD symptoms must not be better explained by another mental disorder (e.g., bipolar disorder)

to their current academic performance.

Classroom and special education teachers are typically the initial source of a referral when a child’s skill development begins to impact their academic performance (Sugden & Wright, 1998). An educational psychologist administers a series of standardized tests to the child to assess their level of ability compared to what is considered normative for their age and developmental level. If learning difficulties are revealed based on their performance on these various tests, the educational psychologist refers the child to a trained professional such as a psychiatrist for a formal diagnosis. In order for a differential diagnosis to be made, it first must be determined whether the difficulties displayed are due to other sensory, motor, cognitive, emotional, environmental, and cultural factors.

Children with movement difficulties that substantially impact their academic achievement or activities of daily living are diagnosed with DCD (APA, 2013). Family members, classroom teachers, and researchers may be the first to recognize associated characteristics among children. However, a developmental pediatrician generally makes the diagnosis with a team of professionals, including physical and occupational therapists, whom play an integral role in the diagnostic process (Missiuna, Rivard, & Bartlett, 2003).

Professionals in both the health care and educational systems often do not initially recognize children that demonstrate characteristics associated with a diagnosis of DCD because the disorder is not well known or understood (Missiuna, Moll, Law, King, & King, 2006). As a result, these children are not diagnosed until years after they have begun to experience significant movement difficulties. Moreover, the information obtained from assessments used by physical therapists to examine these children is limited with respect to how their movement difficulties impact activities of daily living, which is one of the diagnostic criteria required for formal diagnosis. Teacher identification has become more common in school-based research, where children are considered to be at risk for or have probable DCD when their performance in physical education is compared relative to their classmates. Following teacher referral, children are then assessed for motor impairment by the researcher (e.g., Cairney et al., 2007).

The *Movement Assessment Battery for Children* (*MABC-2*; Henderson, Sugden, & Barnett, 2007) is most often used to identify school-aged children with or at risk for DCD. Each child's results are compared to normative data to provide researchers and educators with information pertaining to their range of impairments spanning across three domains (manual dexterity, ball skills, and balance). A total test score at or below the 5^{th} and 15^{th} percentiles indicates those children with definite or borderline (at risk for) motor impairment, respectively.

Prevalence estimates of school-aged children with difficulties in the motor domain vary among countries from 1.8% reported in the United Kingdom (Lingam, Hunt, Golding, Jongmans, & Emond, 2009) to as high as 19% in Greece (Tsiotra et al., 2006). Prevalence rates may vary across countries because of the process used to recognize, refer, and diagnose children with DCD. In North America, 5 to 6% is most frequently reported (APA, 2000), yet many of these children do not receive the appropriate services to address their movement difficulties. Relying exclusively on children who already have a formal diagnosis for inclusion in research may underestimate the prevalence rates and our understanding of the range of impairments experienced among children who demonstrate difficulties in the motor domain.

The diagnostic criteria for DCD have remained the same since the *DSM-IV*, based on the information available on the *DSM-V* (APA, 2013). This suggests the diagnosis of DCD and the practices related to the provision of services may have also failed to change in over a decade, even with the notable similarities in diagnostic criteria for LD and DCD. The diagnostic criteria for both LD and DCD acknowledge that deficits must significantly impact academic achievement and activities of daily living. Physical education is part of the core curriculum in Canadian schools, but why is it that (learning) difficulties displayed in physical education are not included as part of LD? This rationale is supported by previous research that has reported approximately 50 to 62% of children with LD also experience difficulties in the motor domain (Miyahara, 1994; Pieters, Desoete, Roeyers, Vanderswalmen, & Van Waelvelde, 2012; Vuijk, Hartman, Mombarg, Scherder, & Visscher, 2011). Given that both disorders are neurodevelopmental in nature, learning difficulties demonstrated in the classroom would be expected to extend to other academic areas such as physical education.

1.1.1 Issues with Identification and Prevalence Estimates

The prevalence of LD has increased 5.5% in the last 15 years, with approximately 8% of school-aged children having a formal diagnosis (Centers for Disease Control and Prevention, 2011). The *DSM-V* has recognized some concerns in the literature regarding the identification process for children with LD. Varying prevalence rates are partly attributed to false positive (over-identification of students with high IQ and average achievement) and false negative (under-identification of students with low IQ and below average achievement) outcomes resulting from the application of the discrepancy formula (Berkeley, Bender, Peaster, & Saunders, 2009). However, the lack of agreement for what “discrepancy” refers to in the context of learning and the variety of instruments used among professionals in its determination also contributes to increased or varying prevalence estimates (Fuchs, Fuchs, & Compton, 2004).

Long-standing discussions about appropriate identification of DCD also exist in the literature. Although 5 to 6% of children between 5 to 11 years of age are considered to have DCD, these difficulties are often overlooked when other childhood disorders are also present (Wilson, 2005). Moreover, varying methods and cutoff scores are used among researchers to identify children at risk for DCD for inclusion in research (Dewey, Kaplan, Crawford, & Wilson, 2002). The use of different measurement tools and percentiles (e.g., the 5^{th} versus the 15^{th} percentile) may influence prevalence rates of DCD. The *MABC* is one of the most frequently used assessments for examining motor impairment among children, however, not all researchers agree it is the best tool for identifying movement difficulties (Venetsanou et al., 2011).

Prevalence estimates of DCD may also be impacted by teachers’ perceptions of, and expectations for, movement performance. Previous research has reported that teachers’ perceptions seem to be influenced by the sex of the child, with more boys being identified as having gross motor difficulties (Geuze & Kalverboer, 1987; Missiuna, 1994; Mon-Williams, Wann, & Pascal, 1997; Rivard, Missiuna, Hanna, & Wishart, 2007) and more girls as having fine motor difficulties (Rivard et al., 2007). These research findings support the notion that teachers may observe and assess motor abilities in boys and girls differently based on the type of motor task they demonstrate difficulty with (Toole & Kretzschmar, 1993).

1.2 Overview of Underlying Processes

Learning is an internal phenomenon that cannot be directly assessed because it is not observable (Ives, 2013). However, learning can be inferred from performance measurements across multiple time points. For the most part, performance scores provide an indication of what has been learned. The performance of both academic and movement tasks rely on higher-level cognitive processes such as planning, organizing, and problem solving (Naglieri & Das, 1997; Wall, Reid, & Harvey, 2007). These processes, referred to as executive functions, are located in the prefrontal cortex of the frontal lobe.

School-aged children with LD (Pieters et al., 2012; Vuijk et al., 2011) and DCD (Green et al., 2002; Kane & Bell, 2009) have been found to demonstrate motor impairment for tasks that require manual dexterity, ball skills, and balance. Difficulties in motor control and learning that in turn impact performance may be attributed to automaticity deficits (in the cerebellum) that are thought to be present in children with LD and DCD (Nicolson & Fawcett, 2007). The performance of a skill can become relatively automatic with practice, where one can perform it with less attentive control (Nicolson, Fawcett, Brookes, & Needle, 2010). As a result, more cognitive capacity can be used to focus on other factors that will contribute to improved performance.

There are two main routes that involve connections between the cerebral cortex and the cerebellum: a motor route (between the primary motor cortex in the frontal lobe and the cerebellum) and a cognitive route (between the prefrontal cortex and the cerebellum; Balsters et al., 2010; Ramnani, 2006). Given that both children with LD and DCD exhibit deficits in executive functioning, it may offer some explanation as to why they appear to demonstrate similar levels of motor impairment.

1.3 Overview of Difficulties in the Performance of Fundamental Movement Skills

School-aged children with LD and DCD experience difficulty in numerous facets required to successfully perform fundamental movement skills compared to their same-aged peers. Some of these difficulties include greater variability in their movement patterns used (Rosengren et al., 2009; Utley & Astill, 2007) and aspects of movement such as force (Smits-Engelsman, Westenberg, & Duysens, 2008) that contribute to overall performance. These difficulties may also constrain their ability to utilize movement skills in organized activities or sport (Jarus, Lourie-Gelberg, Engel-Yeger, & Bart, 2011). Whether these difficulties are demonstrated for all or only certain movement skills is largely unknown.

1.4 Overview of the Activity Deficit Hypothesis

Impaired performance of movement skills is likely to impact children’s participation in physical activity, placing them at greater risk for health consequences associated with inactivity. The belief that children with movement difficulties may be less active than their typically developing peers of the same age is referred to as the activity deficit hypothesis (Bar-Or, 1983; Wall, 1982). Cross-sectional studies that have examined this hypothesis found children at risk for DCD engage in significantly less vigorous activity compared to their peers (Cairney, Hay, Faught, Corna & Flouris, 2006) and spend more time alone (Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996). Longitudinal research has added to those findings and reported a decrease in physical activity participation with age (Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2010). The presence of movement difficulties at an early age may predict physical activity levels in later life (Green et al., 2011). As such, these results underscore the necessity for early intervention among children with movement difficulties to help them develop the skills necessary to engage in increased physical activity.

1.5 Research Objectives

Mastery of fundamental movement skills is an important precursor for participation in physical activity (Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006), which is integral to leading a healthy and active lifestyle. Research has shown that school-aged children with LD (Woodard & Surburg, 2001) and DCD (Van Waelvelde, De Weerdt, De Cock, Smits-Engelsman, & Peersman, 2004) differ from their same-aged peers in the performance of movement skills and may participate less in moderate-vigorous physical activity (MVPA; Bouffard et al., 1996). This research aims to describe the similarities and differences in the underlying processes and aspects impaired in the (learning and) performance of movement skills, and the relationship to physical activity, among students who demonstrate difficulties spanning across multiple academic areas. Because identification of children with LD or DCD is a complex and often inconsistent process, this research will include students who have either received a formal diagnosis or demonstrate difficulties in reading, writing, math, and/or physical education.

In order to receive a formal diagnosis, children are required to meet specific diagnostic criteria; however, recognition of these criterion and the measures used to assess them are generally not agreed upon (Dewey et al., 2002). Children who demonstrate difficulties with learning in the classroom or performing movement skills in physical education, but not to an extent that would warrant a definitive diagnosis, tend to be overlooked. Because many of these children do not receive the appropriate services to address their difficulties in various academic areas, they may miss out on important opportunities to improve their academic and/or movement performance. It is important to obtain greater understanding of the range of difficulties these children experience at an early age before the gap in their performance, compared to same-aged peers, widens and intervention is less effective. Students who were currently receiving additional instruction or services for academic purposes at school are referred to as students with academic difficulties (AD) and those who demonstrated difficulties in the performance of movement skills are referred to as having movement difficulties (MD). Since academic and movement difficulties often go unrecognized until early years of formal schooling, when children are challenged to meet increasing expectations, students 7 to 10 years of age were targeted in this research.

The specific aims of this thesis were three-fold: (1) to compare motor and executive functioning abilities among students with AD and MD to examine similarities and differences in levels of impairment underlying the performance of movement; (2) to compare movement performance between students with AD, MD, and their typically developing peers to describe similarities and differences in their performance of fundamental movement skills; and (3) to examine physical activity levels for each of the three groups and subsequently, the relationship between movement performance and physical activity. This more comprehensive and individualized examination of the range of impairments experienced in each student will contribute to the development of appropriate instruction and intervention, versus examining impairments associated with each diagnosis alone.

1.5.1 Hypotheses

(1) Based on previous literature (Miyahara, 1994), approximately 50% of students with AD are expected to demonstrate MD, with similarities in motor impairment being demonstrated among students in both groups. Students with motor impairment are also expected to demonstrate greater levels of impairment in executive functioning. (2) When the performance of fundamental movement skills by students with AD and MD are compared to typically developing students, students with AD and MD should demonstrate less proficient performance. Students with AD who also demonstrate MD and students with MD should demonstrate impairments in the same skill areas that impact their performance. (3) Students with proficient movement skills should demonstrate greater physical activity levels because of their ability to use and practice these skills in a variety of activities. This means typically developing students should spend more time in MVPA compared to students with AD and MD. Significant correlations are expected between students' proficiency in the performance of movement skills and their physical activity levels.

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CHAPTER 2: Motor Abilities and Executive Functioning among Students with Academic or Movement Difficulties

Students may experience various types of learning difficulties, with reading, writing, and math being the most common areas identified. Because of the impact these learning difficulties have on academic achievement, they often take precedence over similar difficulties that students may have in physical education (Wilson, 2005). However, many students who have difficulty meeting age expectations for academic achievement in the classroom also have difficulty performing fundamental movement skills with the same level of proficiency as their peers (Westendorp, Hartman, Houwen, Smith, & Visscher, 2011; Woodard & Surburg, 1997, 2001).

With respect to the acquisition and performance of movement skills, students with learning disorders (LD) and developmental coordination disorder (DCD) demonstrate similar and overlapping impairments (Dewey, Kaplan, Crawford, & Wilson, 2002; Kaplan, Wilson, Dewey, & Crawford, 1998; Nicolson & Fawcett, 2007). Given this overlap, is it possible that difficulties experienced in physical education may be indicative of a (motor) learning disorder? For this reason, students who experience difficulty learning (and performing) in the classroom may be more similar than different to those students who have difficulty performing in the gymnasium. However, many students with learning or movement difficulties do not receive a formal diagnosis or the appropriate services to address their difficulties. As such, the purpose of this paper was to describe the processes thought to underlie the learning and performance of movement skills among students with demonstrable difficulties in various academic areas, but who may not meet diagnostic criteria for LD or DCD.

2.1 Motor Abilities

Motor abilities reflect underlying capacities or processes that contribute to the performance of movement skills (Burton & Miller, 1998). Assessments that evaluate motor abilities consist of several movement tasks grouped into one or more ability areas such as balance or coordination, to measure the traits that are thought to underlie and contribute to the performance of a variety of movement skills. Since these traits are not directly observable, they must be inferred from performance (Burton & Miller, 1998). The most commonly used assessments that serve as screening tools for the inclusion of children and adolescents with motor impairment in research or to examine the degree of one's motor impairment include the *Movement Assessment Battery for Children* (*MABC-2*; Henderson, Sugden, & Barnett, 2007) and the *Bruininks-Oseretsky Test of Motor Proficiency* (*BOTMP-2*; Bruininks & Bruininks, 2005). Both assessments evaluate children and adolescents on age-related tasks for different skill domains under the assumption that as children get older, they should be able to complete tasks of increasing complexity and with greater levels of proficiency.

A student's degree or level of motor impairment is determined by converting the raw scores on each task to standard scores and percentiles, which are reflective of their performance relative to the normative data of their same-aged peers. Generally, total test scores at or below the 5th percentile indicates definite motor impairment, at or below the 15th percentile indicates borderline motor impairment, and greater than the 15th percentile indicates no impairment. The research on motor abilities discussed in this paper employed various cutoff scores such as the 5^{th} and 15^{th} percentiles in the administration of the *MABC* and *BOTMP*.

When examining the motor abilities of school-aged children with LD, approximately 50 to 62% demonstrate motor impairment (Miyahara, 1994; Pieters, Desoete, Roeyers, Vanderswalmen, & Van Waelvelde, 2012; Vuijk, Hartman, Mombarg, Scherder, & Visscher, 2011). However, one study found as many as 88% of children with LD to also demonstrate movement difficulties (Miyahara, 1997). Two main subtypes of children with LD have been suggested according to their gross motor function: those who demonstrate movement difficulties and those who do not (Miyahara, 1994). Particular difficulties were demonstrated for balance and coordination, which primarily impacted their running speed and performance for ball skills on the *BOTMP*.

Other research has found substantial impairments among children with LD on all three domains of the *MABC* (Pieters et al., 2012; Vuijk et al., 2011). The percentage of children with LD who performed at or below the 5th percentile on the total test ranged from 35 (Vuijk et al., 2011) to 44 (Pieters et al., 2012). Compared to their peers, greater levels of impairment were demonstrated among children with LD for tasks requiring manual dexterity, ball skills, and balance respectively (Vuijk et al., 2011). However, another study found that children with LD demonstrated the greatest difficulties for balance, manual dexterity, and then ball skills (Pieters et al., 2012).

Impairments have been found among children with DCD for fine motor, gross motor, and upper limb coordination (or ball skills) on the *BOTMP* in both research (Hemmati, Amiri, Soleimani, & Dadkhah, 2008) and clinical studies (Kane & Bell, 2009). Children with a comorbid diagnosis of DCD and LD or ADHD also demonstrate significant impairments on the complete battery of the *BOTMP* based on clinical case reports (Kane & Bell, 2009). However, studies that have used the *MABC* found children with comorbid LD and DCD demonstrate greater impairment on manual dexterity and balance tasks compared to children with DCD alone (Jongmans, Smits-Engelsman, & Schoemaker, 2003). Children with DCD appear to demonstrate the greatest level of impairment for ball skills compared to the other two domains of the *MABC* (Green et al., 2002).

2.2 Executive Functioning

Performance of movement skills also depends on executive functions, which Pribram (1973) defined as a broad range of cognitive processes that are governed by the prefrontal cortex. For example, planning, attention, and simultaneous and successive (or sequential) coding are said to be interrelated components of cognitive functioning (Naglieri & Das, 1997). They are not only important for movement performance, but achievement in academic skills such as reading comprehension (Naglieri & Das, 1997) and math (Kroesbergen, Van Luit, Van Lieshout, Van Loosbroek, & Van de Rijt, 2009). Significant relationships have been found between planning and simultaneous coding and total test scores on the *MABC* (Asonitou, Koutsouki, Kourtessis, & Charitou, 2012). Given that children with LD (Fawcett & Nicolson, 1995) and DCD (O'Brien, Williams, Bundy, Lyons, & Mittal, 2008) both exhibit deficits for these (underlying) cognitive processes, executive functioning may contribute to their similarities in motor impairment.

Self-regulation also plays an important role in the planning and performance of goal-directed behaviours (Wall, Reid, & Harvey, 2007). Children with LD (Montague, Applegate, & Marquard, 1993) and DCD (Missiuna, Malloy-Miller, & Mandich, 1997) are believed to demonstrate poor ability to regulate and monitor their performance across a variety of tasks. Studies that have examined self-regulation for sport-specific tasks found that children with DCD demonstrated particular difficulty monitoring and evaluating their performance (Lloyd, Reid, & Bouffard, 2006; Martini, Wall, & Shore, 2004). As a result, these children verbalized significantly less accurate planning strategies during hockey shooting and ball catching tasks. For example, a child may say the ball needs to be thrown softer, when it actually needs to be thrown harder to improve performance (Martini et al., 2004). In addition, children with DCD demonstrated difficulties identifying the source of their performance errors (Lloyd et al., 2006). As such, it seems plausible that children with DCD may demonstrate impaired performance of movement skills largely due to difficulties in learning and applying cognitive strategies during the movement process.

Although research has examined children identified as having LD or DCD individually and found similar levels of impairment, underlying processes have not been compared between the two groups directly. The objective of this study was to compare the motor abilities and parental report of executive functioning among students 7 to 10 years of age who were specifically identified as having demonstrable difficulties in the classroom or gymnasium. Based on previous research, it was hypothesized that about 50% of students with academic difficulties (AD) would also demonstrate motor impairment on the *MABC-2*. It was also hypothesized that students with AD who also demonstrated movement difficulties would exhibit similar levels of impairment as those students who were identified based on their movement difficulties alone. Regardless of how they were identified, students who demonstrate motor impairment would also be expected to have greater levels of impairment for executive functioning.

2.3 Methods

2.3.1 Participants

Students aged 7 to 10 were recruited from three elementary schools located in close proximity within the Regina Public School system; all schools had learning resource programs. Learning resource teachers at each school referred students with AD who were currently receiving additional instruction and services for academic purposes (e.g., reading, writing, math). The primary researcher was involved in physical education classes prior to the study to help classroom teachers identify students with movement difficulties (MD) through observation. Particular attention was paid to those students who demonstrated difficulty with ball and balance skills as well as the ability to run smoothly and stop with control.

Students with sensory deficits, cognitive impairments, or other developmental disabilities (e.g., autism) were not recruited for participation. Initially, 12 students with AD were recruited for participation based on teacher referral. However, the eight students with AD who also scored below the 16th percentile on the *MABC-2* were of particular interest. As such, comparisons were made between 8 students with AD (M_{age} = 9.65 years, SD = 0.85) and 12 students with MD (M_{age}= 8.84 years, SD = 0.95). The AD group was comprised of 4 boys and 4 girls, while the MD group included 8 boys and 4 girls. Students who demonstrated characteristics associated with a diagnosis of ADHD were not excluded from this study since they represent the true range of difficulties experienced by students with academic and movement difficulties (Dewey et al., 2002; Iversen, Berg, Ellertsen, & Tonnessen, 2005; Jongmans et al., 2003; Kadesjö & Gillberg, 1999; Watemberg, Waiserberg, Zuk, & Lerman-Sagie, 2007). However, only 1 student in the AD group had a formal diagnosis of ADHD.

2.3.2 Measures

Levels of motor impairment were assessed using the second age band (7-10 years) of the *MABC-2* (Henderson, Sugden, & Barnett, 2007). Tasks within this age band are subdivided into three domains: (a) three tasks of manual dexterity, (b) two tasks of manipulative skills, and (c) three tasks of static and dynamic balance. For each task, raw scores were converted to standard scores, which facilitated comparison to norms established with students of the same age. The item standard scores were summed together to obtain component scores for each domain. The component scores for each of the three domains were added together to derive a total test score. Lower component and total test scores reflect greater levels of impairment. A total test score at or below the 5th percentile indicates definite motor impairment, while a score at or below the 15th percentile indicates borderline motor impairment. A total test score less than or equal to the 16th percentile across all three domains was used to identify students with MD in this study because standard scores associated with the 15th percentile were not provided.

The long form of the *Barkley Deficits in Executive Functioning Scale – Children and Adolescents* (*BDEFS-CA*; Barkley, 2012) was also used to facilitate understanding of executive functioning and self-regulatory skills among students with AD and MD. It is a 70-item parent rating scale that examines five components of executive functioning for children and adolescents aged 6 to 17 years: (a) self-management to time, (b) self-organization, (c) self-restraint, (d) self-motivation, and (e) self-regulation of emotion. The scale is divided into two age bands (6-11 and 12-17), with raw scores and percentiles further divided by sex. In this study, executive functioning abilities were assessed using the 6 to 11 age band. Parents were asked to rate the occurrence of each item or activity of daily living based on the previous 6 months using four anchor points: not at all or rarely (1), sometimes (2), often (3), and very often (4). The selected anchor points for each executive functioning component were summed individually to obtain a total score. The total score for the five components were then summed to obtain a summary score.

Higher total and summary scores, as well as percentiles, indicate greater level of executive functioning impairment. Based on parents' perceptions, students who scored between the 85^{th} and 92^{nd} percentiles were considered to be borderline or somewhat deficient in their executive functioning skills, mildly deficient between the 93^{rd} and 95^{th} percentiles, and moderately deficient between the 96^{th} and 98^{th} percentiles. Students' executive functioning was viewed as markedly deficient or severe if they scored at the 99^{th} percentile. For purposes of this study and to parallel the percentiles (e.g., 5^{th} and 15^{th} percentiles) and terminology used in the *MABC-2*, the borderline and mildly deficient categories were combined to reflect impairment between the 85^{th} and 95^{th} percentile, which will be referred to as borderline impairment. The moderate and severe categories were also combined to reflect impairment greater than or equal to the 96^{th} percentile, which will be referred to as definite impairment.

The ADHD executive functioning index score was also derived from the *BDEFS-CA* to provide insight into additional impairments these students may experience. There are 10 items included throughout the scale that reflect deficits of executive functioning common in ADHD. Raw scores associated with the 94^{th} and 93^{rd} percentile for boys and girls respectively, indicate behaviours and symptoms commonly associated with a diagnosis of ADHD.

The relationships among the different components of the scale are significantly ($p < .001$) and moderately to highly correlated (Barkley, 2012). The internal consistency of each component was computed based on a sample of 1,922 children and adolescents and was found to be quite satisfactory, $r = .987$. The test-retest reliability of the scale was then analyzed by having 86 parents of the children and adolescents sampled to complete the scale on a second occasion 3 to 5 weeks later. All Pearson product-moment correlations between the first and second administration were moderate to high (p < .001). Construct validity was assessed by having 22 parents of children between the ages of 6 to 17 years complete both the *BDEFS-CA* and the *Behavior Rating Inventory of Executive Function* (*BRIEF*). Significant correlations ($p < .001$) were found between components of each scale. When children with a clinical diagnosis of DCD were compared to those without DCD to determine criterion validity, significant differences ($p < .003$) were found for all components of the scale, as was the case for comparisons between children with and without LD.

2.3.3 Procedure

Ethics approval was obtained from the University of Regina Research Ethics Board, followed by the Regina Public School Board. A member of the school board selected schools with learning resource programs to facilitate the identification of students with AD. Students with AD and MD were identified as potential participants by the learning resource and classroom teachers. Informed consent forms were sent home with these students to obtain consent from their parents or guardians and each student's assent.

Participants were then individually assessed on the *MABC-2* in a 15 to 20 minute session during school hours by two researchers; one trained in the administration of the *MABC-2* and one graduate student in training. Standard protocol were followed in the administration of the assessment with instructions and a demonstration provided prior to the student's performance of each task. As per administration protocol, for tasks where two trials are required (e.g., placing pegs), the best trial for that task was scored. For other tasks (e.g., drawing trail and balance tasks), if a student completed the first trial and obtained the highest score possible, a second trial was not administered. Component scores for each of the three domains and a total test score were calculated to determine the extent of motor impairment.

Following administration of the *MABC-2*, the *BDEFS-CA* was sent home for each student's parent or guardian to complete. A cover letter was included with the scale to inform parents of its intended use and instructions for completion. Parents were asked to return the completed scale in a sealed envelope to their child's classroom teacher. The *BDEFS-CA* was scored following it being returned.

2.4 Results

All analyses were performed using SPSS version 18.0 with alpha set at .05. Group descriptive statistics for component scores, standard scores, and percentiles of each domain and the total test of the *MABC-2* are reported in Table 2. With regard to the *MABC-2* results, effect sizes of 0.2, 0.5, and 0.8 were considered small, moderate, and strong for this study (Thomas, Nelson, & Silverman, 2011).

Table 2

Group descriptive statistics for component scores, standard scores, and percentiles of each domain and total test scores of the MABC-2

	AD (n = 8)	MD (n = 12)
Manual dexterity		
Range of component scores	12.50 – 26.00	8.50 - 33.00
Component score	18.81(6.30)	20.00(7.68)
Standard score	6.13(2.47)	6.58(2.87)
Percentile	16.00(17.55)	20.58(23.84)
Ball skills		
Range of component scores	15.00 – 21.00	8.00 - 18.00
Component score	17.38(2.83)*	12.08(3.50)*
Standard score	9.13(1.36)	5.25(2.67)
Percentile	39.13(17.16)	11.88(13.02)
Balance		
Range of component scores	8.50 – 24.50	7.50 - 22.50
Component score	18.75(6.28)	16.04(5.73)
Standard score	5.50(2.27)	4.42(2.07)
Percentile	10.63(8.26)	5.76(5.14)
Total test		
Range of component scores	39.00 – 66.50	33.00 - 64.50
Component score	54.94(8.52)	48.13(11.35)
Standard score	5.25(1.28)	4.33(1.83)
Percentile	7.00(4.81)	5.25(5.88)

AD = Academic difficulties; MD = Movement difficulties

Note: Means and (standard deviations) are reported for all scores and percentiles of each domain and the total test, with the exception of the range of component scores

* $p < .01$

A one-way analysis of variance (ANOVA) was conducted with the AD and MD groups as the independent variable and the total test scores (sum of component scores) on the *MABC-2* as the dependent variable. Results of the ANOVA were not statistically significant, $F(1, 18) = 2.08$, $p = .17$. The strength of the relationship between groups and the total test scores, as assessed by η^2, was small with the group accounting for 10.4% of the variance.

To further explore the similarities in motor impairment between groups on the *MABC-2*, a Pearson correlation was performed to determine if a multivariate analysis of variance was appropriate for examining impairment on the manual dexterity, ball skills, and balance domains collectively. A significant relationship ($r = .532$, $p = .007$) was revealed between ball skills and balance, but neither of those domains was related to manual dexterity. Therefore, three independent samples t-tests were conducted with the AD and MD groups as the independent variable and component scores (sum of the item standard scores) for manual dexterity, ball skills, and balance as the dependent variables. Significant differences in performance were not revealed between the two groups for manual dexterity [$t(18) = -.36$, $p = .72$] and balance [$t(18) = 1.00$, $p = .33$]. However, students with AD and MD demonstrated different levels of impairment for ball skills [$t(18) = 3.56$, $p = .002$]. Refer to Table 3 for the frequency of students with AD and MD who demonstrated definite and borderline levels of impairment for each domain of the *MABC-2*.

Table 4 includes group descriptive statistics for each component of the *BDEFS-CA*, as well as the summary scores and ADHD index. Rating scales were not returned for 1 student with AD and 4 students with MD. Based on the completed parent rating scales,

Table 3

Frequency of students with AD and MD that scored at or below the 5th and 16th percentile for each skill domain and the total MABC-2 test

	AD (*n* = 8)		MD (*n* = 12)	
	5th percentile	16th percentile	5th percentile	16th percentile
Manual dexterity	4	5	5	8
Ball skills	0	0	7	8
Balance	5	7	6	12
Total test	4	8	8	12

AD = Academic difficulties; MD = Movement difficulties

Table 4

Group descriptive statistics for BDEFS-CA component, summary, and ADHD index scores

	AD (n = 7)	MD (n = 8)
Self-management to time		
Range of raw scores	27.00 – 43.00	15.00 – 44.00
Raw score	34.43(5.68)	27.00(8.60)
Percentile	88.57(6.60)	66.00(23.27)
Self-organize		
Range of raw scores	23.00 – 47.00	14.00 – 30.00
Raw score	34.29(10.52)	20.50(4.63)
Percentile	90.71(7.89)	67.13(19.81)
Self-restraint		
Range of raw scores	18.00 – 39.00	13.00 – 24.00
Raw score	25.00(7.23)	19.88(4.22)
Percentile	67.14(20.06)	50.88(17.94)
Self-motivate		
Range of raw scores	25.00 – 56.00	17.00 – 49.00
Raw score	37.00(9.63)	27.00(10.64)
Percentile	89.14(7.97)	65.38(22.60)
Self-regulate emotion		
Range of raw scores	20.00 – 48.00	17.00 – 35.00
Raw score	36.00(10.26)	24.88(6.90)
Percentile	77.43(21.52)	55.00(21.36)
Summary score		
Range of raw scores	140.00 – 201.00	89.00 – 182.00
Raw score	166.43(23.16)	119.25(29.29)
Percentile	88.71(6.16)	59.25(20.27)
ADHD index		
Range of raw scores	18.00 – 27.00	11.00 – 24.00
Raw score	22.57(3.46)	15.63(3.96)
Percentile	87.86(7.78)	60.38(21.41)

AD = Academic difficulties; MD = Movement difficulties

Note: Means and (standard deviations) are reported for all executive functioning components and percentiles, with the exception of the range of raw scores

4 students with AD were considered to have borderline impairment and 1 had definite impairment. Of these students, all of them scored above the 85^{th} percentile in motivation, 4 of 5 in self-management to time and self-organization, 3 in self-regulation of emotion, and only 1 for self-restraint. Moreover, 2 of the 5 students demonstrated associated behaviours with a diagnosis of ADHD. Interestingly, only 1 student with MD exhibited borderline impairment in executive functioning, but demonstrated the greatest impairments in the same 3 components as students with AD, which were motivation, self-management to time, and self-organization.

2.5 Discussion

In the present study, 8 of 12 students with AD also demonstrated difficulties in the motor domain as determined by a total test score less than or equal to the 16^{th} percentile on the *MABC-2*. The number of students in this research with AD who also demonstrated MD is slightly higher than the ranges reported in the literature (Miyahara, 1994, 1997; Pieters et al., 2012; Vuijk et al., 2011) and cannot be generalized beyond this due to the small sample size.

In this study, students with AD and MD both demonstrated the poorest performance for placing pegs and threading lace of the manual dexterity tasks. Commonalities were most apparent for speed, accuracy, and the amount force exerted while completing both tasks. For example, students misaligned the pegs with the holes or sometimes missed the hole with the tip of the lace and most students used excessive force when inserting pegs into the board. For students who had difficulty with the drawing trail, they went too fast to be accurate, progressed in short jerky movements, or used excessive force and pressed very hard on the paper.

On the balance tasks, the majority of students who demonstrated MD, regardless of how they were identified, had particular difficulty with the one-board balance and walking heel-to-toe forwards. When attempting the one-board balance, several students used strategies to maintain balance that actually disrupted their balance even further. The use of inefficient strategies may be due to difficulties with identifying the source of their performance errors (Lloyd et al., 2006). In order to improve their performance, some students held their nonsupport leg close to the ground rather than at a 90 degree angle. When walking heel-to-toe forwards, students either walked too fast to maintain accuracy of their foot placement, which resulted in spaces between the heel and toe of opposing feet or their foot shifted off the line, or paused frequently in order maintain accuracy of their foot placement.

However, marked differences between students with AD and MD were revealed for tasks requiring aiming and catching. Nine of 12 students with MD scored less than 5 out of 10 on both ball skill tasks: catching with two hands and throwing a beanbag. Catching with two hands appeared to pose the greatest difficulty for them as 6 of 12 students obtained a score of 0. The main difficulties displayed among students with MD for aiming and catching included judging the appropriate amount of force required or the most efficient movement pattern to generate that amount of force. The majority of students were inconsistent with how much force was used across trials, with only a few students consistently using too little or too much force when throwing the ball or beanbag. These findings are supported by previous research that suggested students with MD struggle with learning from mistakes due to difficulties in monitoring their performance and applying cognitive strategies during the movement process to improve performance on subsequent trials (Lloyd et al., 2006; Martini et al., 2004).

The results of this study are also supported by previous research that used the second age band (7 to 10 years) of the *MABC* to assess motor impairment. Students with AD appear to demonstrate the greatest difficulties for manual dexterity and balance tasks, with no impairment for ball skills (Pieters et al., 2012). Previous research that has examined motor abilities of children with LD aged 7 to 12 reported impairments across all three domains (Vuijk et al., 2011). However, this study would have used two different age bands to assess the children in their research, which may provide some explanation for the incongruent findings with regard to the extent of impairments found in the different domains. Students with MD demonstrate substantial impairment for ball skills, with difficulties in the performance of manual dexterity and balance tasks also present (Green et al., 2002). When students with AD and MD were compared directly, similar levels of impairment were revealed for manual dexterity and balance, but not ball skills.

Students in each group were hypothesized to demonstrate impairment in executive functioning; however, not all students with AD and MD demonstrated definite or borderline levels of impairment. Impairments in underlying cognitive processes were most apparent among students with AD who were 9 and 10 years of age. Cognitive processes develop with increased age and therefore, students should demonstrate similar levels of executive functioning as they get older because their rate of development is more likely to be comparable to others by late childhood. However, differences in executive functioning may be more evident among older students who exhibit impairment in these cognitive processes since they are expected to have developed already, which may explain why only the older students (with the exception of one 7 year old student with MD) were found to demonstrate impairment.

Executive functioning impairment also appeared to be exacerbated among students who experienced a range of difficulties for both academic and movement tasks. More students with MD were expected to demonstrate executive functioning impairment and behaviours associated with ADHD because of overlapping neurodevelopmental constructs between students with AD and MD. However, similar areas appear to be affected (motivation, self-management to time, and self-organization) when students in each group who demonstrated impairments in executive functioning were compared. One student with AD and 2 students with MD who did not return their rating scales scored at or below the 5th percentile on the total test of the *MABC-2*, and the remaining 2 students with MD were at the 9th percentile. This may have impacted the findings as it was expected that students with greater motor impairment would also demonstrate greater levels of executive functioning impairment. However, 5 students with MD who did return the scale also scored at or below the 5th percentile and did not demonstrate impairment in executive functioning.

2.5.1 Limitations

Several limitations were present in this study, primarily related to the size of the sample and the assessments that were used. The sample size was small (8 students with AD and 12 students with MD) and as a result, these findings may not generalize. Further investigation with a larger sample is required to obtain greater certainty with respect to the similarities and differences of impairments found among students with AD and MD in this study, particularly in the realm of executive functioning. Each group was also comprised of students with demonstrable difficulties in various academic areas, rather than focusing on students with a diagnosis. As such, the students in this study may not demonstrate the same extent of difficulties as students with a formal diagnosis and additional factors, aside from neurodevelopment, may be impacting their learning difficulties.

The capacity to examine potential similarities and differences between groups on the *BDEFS-CA* was limited since 4 of 5 questionnaires were not returned from students with MD. As a result, the mean age of the students with MD who did return the parent rating scale was 8.76 (*SD* = 1.08). This is a limitation because the students who did have reported difficulties in executive functioning were 9 and 10 years of age. Having more 9 and 10 year old students in my sample may have better contributed to the understanding of executive functioning impairment between groups. The *BDEFS-CA* is also a new parent rating scale that has not been used extensively in research. Perhaps a more commonly used scale such as the *BRIEF* would have produced different results. The use of actual tasks (e.g., *Tower of London*) that require certain executive functions such as planning and organization in combination with a rating scale may be more beneficial.

Rating scales have the ability to obtain information from parents or guardians who have many years of experience with the child being rated. However, there are inherent disadvantages to using these assessments such as the assumption that there is a shared understanding between the respondent and the examiner with regard to the item being rated. Furthermore, the respondent may interpret the meaning of the anchor points provided on the scale for that item differently (Barkley, 2012). Various factors such as education, range of life experiences, and prior experience with similar rating scales may influence the capacity of the parent or guardian to provide an accurate report of the behaviour included on the scale.

The use of the *MABC-2* may have also produced different results than expected. The *MABC-2* was chosen to assess motor abilities among students since it is one of the more commonly used assessments by both trained professionals and researchers. However, limitations exist within the assessment itself such as the restricted range of tasks for each skill domain and the “functional” nature of tasks (Venetsanou et al., 2011).

2.5.2 Future Direction

The results of this study do not fully support the hypothesis that students with AD and MD would demonstrate more similarities in impairments than differences across all three domains of the *MABC-2*. Students with AD and MD appear to display similar difficulties for manual dexterity and balance skills, but not ball skills. Further investigation is required into similarities of motor impairment with respect to the performance of more “functional” movement skills. Knowledge gained from assessments that examine how movement skills are performed will afford greater understanding of where specific impairments occur among students who demonstrate MD.

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CHAPTER 3: Fundamental Movement Skills among Students with Academic or Movement Difficulties

Childhood obesity is considered one of the most serious public health concerns of the 21st century (World Health Organization, 2012). Until recently, secondary health consequences such as diabetes, cardiovascular diseases, and musculoskeletal disorders have been seen almost exclusively among adults. These health consequences are now increasingly more common among children with approximately 26% of Canadian children being overweight or obese (Tremblay et al., 2010). Energy expenditure, which generally occurs in the form of physical activity, is highly important in maintaining a healthy weight and preventing the development of secondary health consequences associated with inactivity (Pulgarón, 2013).

Mastery of fundamental movement skills is an important precursor for participation in physical activity (Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006), which is integral to leading a healthy and active lifestyle. Fundamental movement skills consist of basic locomotor and object control skills that lay the foundation for more advanced or sport specific skills to emerge in late childhood and early adolescence (Burton & Miller, 1998). Impaired performance of movement skills is likely to impact participation in physical activity, which poses risk for health consequences associated with inactivity or sedentary behaviour (Cairney et al., 2010). School-aged children with developmental coordination disorder (DCD) demonstrate impaired performance of fundamental movement skills compared to their same-aged peers (e.g., Lefebvre & Reid, 1998; Utley & Astill, 2007). However, children with learning disorders (LD) also differ from their peers in the performance of these skills (Westendorp, Hartman, Houwen, Smith, & Visscher, 2011), with over 50% also demonstrating some degree of movement difficulties (Miyahara, 1994; Pieters, Desoete, Roeyers, Vanderswalmen, & Van Waelvelde, 2012; Vuijk, Hartman, Mombarg, Scherder, & Visscher, 2011; Woodard & Surburg, 2001).

Limited research has examined the performance of movement skills by children with LD with respect to how individual skills are performed. Studies that have examined the performance of fundamental movement skills by children with LD ages 6 to 12 have produced conflicting results. Relative to normative data, one study reported that children with LD performed poorly with respect to locomotor skills, but performed average on object control skills (Zhang, 2001). However, when compared to typically developing peers, children with LD demonstrated significant difficulty on both locomotor and object control skills (Westendorp et al., 2011; Woodard & Surburg, 2001). The range of movement skills impacted in these children is largely unknown, as well as the similarities in impairment demonstrated in those with LD and DCD.

3.1 Impaired Performance of Individual Movement Skills

Movement performance is a broadly used term that refers to observable, goal-directed movements that can be described in terms of quality or quantity (Burton & Miller, 1998). Qualitative descriptors of performance refer to the movement form or pattern used to execute a particular skill whereas quantitative descriptors focus on products or outcomes with regard to the intended movement goal (Burton & Miller, 1998). Examining how movements are performed as well as the outcome of that movement may provide greater understanding of where specific difficulties in movement occur.

Children with DCD tend to demonstrate shorter strides, higher cadence (Deconinck et al., 2006a; Deconinck, Savelsbergh, De Clercq, & Lenoir, 2010), longer foot contact times (Chia, Licari, Guelfi, & Reid, 2013), and greater variability in movements of the lower limbs (Rosengren et al., 2009) for walking and running compared to their typically developing peers. These difficulties may be the result of a lack of neuromuscular strength (Raynor, 2001) and postural control (Kane & Barden, 2012) in children with DCD, which may impact their performance of other locomotor skills requiring similar movement patterns. Given that children with LD demonstrate similar gait characteristics as children with DCD (Moe-Nilssen, Helbostad, Talcott, & Toennessen, 2003), these underlying mechanisms may also contribute to their difficulties in performance.

Many children with DCD demonstrate significant difficulty catching a ball (Astill, 2007; Deconinck et al., 2006b; Lefebvre & Reid, 1998; Utley & Astill, 2007; Utley, Steenbergen, & Astill, 2007; Van Waelvelde, De Weerdt, De Cock, Smits-Engelsman, & Peersman, 2004), which is an integral part of participation in children's games and sport. In order to catch a ball successfully, a child has to coordinate their movements in advance and under the constraints of a continually changing environment (Ricken, Savelsbergh, & Bennett, 2004). The speed, direction, weight, and size of the ball may influence the timing of their hand movements with respect to reaching and bringing both hands together to grasp the ball.

The ability to predict a ball's line of flight or trajectory is also a key component to the outcome of a catch. Determining the final location of the ball may in fact be the most crucial component for successful performance (Lefebvre & Reid, 1998). Children with DCD require more viewing time and visual information to predict the ball's line of flight compared to their typically developing peers (Lefebvre & Reid, 1998). These findings support previous contentions that children with DCD make less use of anticipatory control (van der Meulen et al., 1991). Anticipatory motor control refers to the preparatory movements that occur both before and during a task, as well as those that support the movement (Schmidt, 1988). Children with DCD may use less information in advance of their movements which influences their ability to predict where the ball will end up, move their bodies to that location, and ultimately catch the ball.

The unpredictable nature of ball trajectories also influences inter- and intra-limb coupling during two-handed catching (Astill, 2007). Children with DCD demonstrate more successful catching performance when the ball is thrown to the middle than on either side of their body, since their limbs move an equal distance to arrive at the same end point. Projections of the ball to either side of the body are considered to be more challenging because the left and right arms are required to move unequal distances, yet make contact with the ball at the same time (Astill, 2007). Impaired performance among children with DCD may be explained by a lack of symmetry between upper limbs during the response phase of catching and the timing of their arm movements (Sekaran, Reid, Chin, Ndiaye, & Licari, 2012). Difficulties in predicting the trajectory of a ball may also explain why some children with DCD tend to step or jump when a ball is thrown directly to their body (as opposed to either side) even though the task characteristics do not demand such action (Przysucha & Maraj, 2010).

Children with DCD have been found to demonstrate increased variability and immature movement patterns with respect to their arms, hands, and body compared to their same-aged peers (Utley & Astill, 2007). Some children turned the palms of their hands up as they waited for the ball, while others trapped the ball against their chest to catch it. When 8 and 9 year old children with DCD were matched to 5 to 7 year old typically developing children who caught a similar number of balls, older children with DCD demonstrated significantly less efficient movement patterns with a higher ratio of grasping errors (Van Waelvelde et al., 2004).

A higher number of grasping errors among children with DCD have also been reported for one-handed catching. A grasping error occurs when the ball hits the palm of the hand and/or fingers or when the closure of the hand is not timed properly (Elliott, Zuberec, & Milgram, 1994). Some children with DCD seem to initiate their hand movements earlier to compensate for difficulties in timing the catch (Estil, Ingvaldsen, & Whiting, 2002), but do not appear to demonstrate these difficulties in order to grasp the ball (Deconinck et al., 2006b). Difficulties with timing may be associated with the ability to predict factors such as the speed, weight, size, and/or direction of the ball (Van Waelvelde et al., 2004). Children with DCD use less information prior to skill execution and therefore, heavily rely on visual information during the task to guide their movements.

Children with LD may have particular difficulty recalling the proper sequence needed to perform movement skills (Fawcett & Nicolson, 1995). Serial ordering and integration of individual movement components are considered key aspects of efficient movement performance (Kowalski & Sherrill, 1992). However, it is unknown whether this phenomenon affects all or only certain movement skills and to what extent. The majority of research has focused on the impaired aspects of performance for individual movement skills (mainly catching) among children with DCD. This research aims to provide greater understanding of the aspects impaired in the performance of a variety of fundamental movement skills among students with academic difficulties (AD) and movement difficulties (MD), by comparing performance to their typically developing peers.

Because identification of students with LD or DCD is a complex process, many students who demonstrate behaviours associated with either of these disorders may not receive a formal diagnosis or the appropriate services to address their difficulties in various academic areas. Although 5 to 6% of school-aged children demonstrate difficulties in the motor domain (American Psychiatric Association, 2000), these students may not be provided with opportunities to improve their (learning and) performance of movement skills. Knowledge gained from this research is valuable in contributing to the development of teaching strategies and intervention to help these students acquire the movement skills necessary for them to lead a healthy and active lifestyle.

Students with AD and MD were expected to demonstrate impairment for both locomotor and object control skills compared to their typically developing peers. Similar impairments in the performance of fundamental movement skills should be demonstrated among students with AD and MD on both assessments: the *Test of Gross Motor Development* (*TGMD-2*; Ulrich, 2000) and the *PE-Metrics*. The *TGMD-2* and *PE-Metrics* are comprised of similar fundamental movement skills, but successful performance of these skills requires different levels of complexity. For instance, the *TGMD-2* largely focuses on the performance of static skills and the *PE-Metrics* examines performance of these the same skills while moving. As such, students within each group should demonstrate greater difficulty performing the skills included in *PE-Metrics* compared to the *TGMD-2*, given the dynamic versus static nature of these skills. Once a student masters the movement process of a specific skill, more attention can be placed on the outcome of their performance.

3.2 Methods

3.2.1 Participants

Forty-two students between 7 and 10 years of age were recruited from three elementary schools in the Regina Public School system. All schools were close in proximity and had learning resource programs. Learning resource teachers at each school referred students with AD who were currently receiving additional instruction and services. It should be noted that the two researchers did not subsequently test these students in order to determine their range of learning difficulties. The primary researcher was involved in physical education classes prior to the study to help classroom teachers identify students with MD through observation. Particular attention was paid to students who demonstrated difficulty with ball and balance skills as well as the ability to run smoothly and stop with control. Students with sensory deficits, cognitive impairments, or other developmental disabilities (e.g., autism) were not recruited for participation. Informed consent forms were sent home with students identified with AD or MD to obtain consent from their parents or guardians and each student's assent. Once consent was provided, students with AD and MD were administered the *Movement Assessment Battery for Children* (*MABC-2*; Henderson, Sugden, & Barnett, 2007) to determine their degree of motor impairment and confirm the inclusion criteria for each group.

Initially, 12 students with AD were referred for participation since they were currently receiving additional services or instruction at school. Results of the *MABC-2* indicated that 8 of the 12 students with AD also demonstrated difficulties in the motor domain. Since the primary objective of this study was to examine impairments in movement performance among students with AD and MD, the 4 students with AD who did not demonstrate difficulties extending to the motor domain were not included in the analyses. A typically developing (TD) group was established by the primary researcher and the principal or learning resource teacher at each school in order to make comparisons relative to students with AD and MD. Typically developing students with birthdates approximately 2 months from that of a student with AD or MD, and was of the same sex, were identified as being potential participants. Informed consent forms were sent home with these students to obtain parental consent and student assent.

All students included in this research were between 7 and 10 years of age. Comparisons were made between 8 students with AD (M_{age} = 9.75 years, *SD* = 0.34), 12 students with MD (M_{age}= 8.90 years, *SD* = 0.27), and 18 TD peers (M_{age}= 9.12 years, *SD* = 0.22). There were 4 boys and 4 girls in the AD group, 8 boys and 4 girls in the MD group, and 12 boys and 6 girls in the TD group. The ratio of boys to girls for each group in this study is comparable to population-based studies, which report a ratio of approximately 2:1 for boys to girls (Lingam et al., 2009).

Students who demonstrated characteristics associated with ADHD were included in this study since they represent the true range of difficulties experienced by students with academic and movement difficulties (Dewey, Kaplan, Crawford, & Wilson, 2002; Iversen, Berg, Ellertsen, & Tonnessen, 2005; Jongmans, Smits-Engelsman, & Schoemaker, 2003; Kadesjö & Gillberg, 1999; Watemberg, Waiserberg, Zuk, & Lerman-Sagie, 2007). However, there was only 1 student in the AD group with a formal diagnosis of ADHD.

3.2.2 Measures

The movement performance of each student was assessed using the *TGMD-2* and *PE-Metrics*. The *TGMD-2* (Ulrich, 2000) is a standardized assessment for children 3 to 10 years that examines movement patterns needed for successful performance of fundamental movement skills. These skills are important for more complex skills to develop during childhood and adolescence (Burton & Miller, 1998). The assessment consists of 2 subtests comprised of 6 movement skills each. The locomotor subtest includes the run, gallop, hop, leap, horizontal jump, and slide and the object control subtest is comprised of the strike, dribble, catch, kick, throw, and roll. Each skill is comprised of 3 to 5 performance criteria that are required for mastery of that skill. Scoring focuses on the presence (1) or absence (0) of each performance criteria that is measured over two trials of each task. Composite raw scores for each subtest range from 0 to 48, where higher scores indicate greater movement performance. Raw scores for each student are converted to standard scores and percentiles for comparison to normative data reflecting the performance of typically developing peers of the same age.

The *TGMD-2* provides a developmental framework to examine the movement patterns of foundational skills that should be mastered by age 10. The assessment focuses on the performance of functional skills that students may perform during play and in physical education and it utilizes typical playground and physical education equipment. Administration of the assessment also occurs in a familiar setting for students such as a gymnasium or school playground. These factors contribute to the ecological validity of the *TGMD-2*.

The internal consistency, test–retest, and inter-rater reliability of the *TGMD-2* vary between .85 and .98 for both subtests and the total scores. All items in the *TGMD-2* are considered "good," with discrimination indexes ranging from .38 to .58. Criterion-predictive validity was assessed between the *TGMD-2* subtests and the *Comprehensive Scales of Student Abilities*. Partial correlations were .63 for the locomotor and .41 for the object control subtest. Results from the confirmatory factor analysis showed that the skills representing each subtest are valid indicators of locomotor and object control abilities ($\chi^2 = 280.3$; GFI = .96; AGFI = .95).

The *PE-Metrics* (National Association for Sport and Physical Education [NASPE], 2010) was primarily designed for use by physical educators to assess the movement skills that students need to participate in various physical activities and to improve the quality of instruction. It aims to measure the movement patterns used among students and the outcome of those movements. The assessment is divided into 3 subtests (Kindergarten, Grade 2, and Grade 5), with each subtest targeting the movement skills relevant to that specific age group. It also provides an indication of which movement skills should be mastered as students progress through the grade levels. The Grade 2 subtest was chosen for this study because it assesses the performance of 11 fundamental movement skills that should be mastered by age 10. Many of the skills included in *PE-Metrics* are also examined in the *TGMD-2*. The dance and gymnastics sequences were not assessed because students were not provided with time to create and practice their routines beforehand, which is a part of the standardized administration procedures. Therefore, 5 locomotor (gallop, jump forward, jumping and landing combination, locomotor sequence, skip) and 4 object control (approach and kick a ball, dribble with hand and jog, overhand catch, striking with paddle) skills were examined. For the locomotor sequence, all students were instructed to run, hop, and then gallop to maintain consistency among students in the 3 locomotor skills chosen.

Each movement skill in the *PE-Metrics* is measured according to the level of competence a student displays with respect to specific performance criteria representing a mature movement pattern as well as the outcome of the movement task. If a student was asked to approach and kick a ball, outcome measures would include the distance and accuracy of the ball being kicked. Each movement skill component is scored from 0 to 4, where a higher score reflects greater competence. Composite scores for each movement component indicate the level of competence displayed overall for that particular skill. Competence scores differ for each movement skill as a result of the number of components relevant to that particular skill.

Although the *PE-Metrics* has been used to provide an objective means of assessment in physical education, it has not been modified for use as a research tool. Standard scores are not yet available to examine student performance relative to normative data, but was not a significant limitation for this study as raw scores obtained by students with AD and MD were compared to their TD peers. This assessment is widely used by physical educators in the United States and consultation among them suggests it is a reliable and valid measurement to assess the movement patterns and outcomes that are performed in the context of physical education. To my knowledge, it has not been used in previous research to examine the performance of fundamental movement skills among students, but *PE-Metrics* does have the potential to provide valuable information with respect to MD demonstrated among students as it emphasizes both the qualitative and quantitative aspects of movement.

3.2.3 Procedure

The University of Regina Research Ethics Board and the Regina Public School Board granted approval for this study. Each student's movement performance was assessed using the *TGMD-2* and *PE-Metrics* during the months of May and June. To ensure that the order in which the assessments were administered did not have an effect on the movement performance of the three groups, assessments were counterbalanced equally within each group as well as across the entire sample. Each student was administered both assessments within a two-week period. The *TGMD-2* was administered and scored based on the research protocol outlined in the manual; a demonstration for each skill is required with verbal instructions, followed by a practice trial. A second demonstration was given if the student did not understand the task following the practice trial. The *PE-Metrics* is generally used by physical educators to assess students on age-related movement skills, with the assumption that they have practiced these skills throughout the school year. As such, protocol for this assessment was modified for research purposes to parallel instructions given in the administration of the *TGMD-2*. Students were provided with verbal instructions for each movement skill, and a demonstration if the instructions were not understood.

For 2 of the 3 elementary schools, students were administered both assessments in the school gymnasium. Due to a lack of gym availability at the third school, students were assessed outdoors on a tarmac during morning school hours and not including recess. The equipment used and preparation for each skill (e.g., distance between cones) followed protocol. Students performed the *TGMD-2* and *PE-Metrics* skills in the same sequence as presented in each manual. Students' movement performance on each assessment was videotaped for later scoring. A trained research assistant who was not aware of the age and group of each student was the primary scorer for all assessments.

To ensure accuracy of scoring, the primary researcher scored 30% of both assessments for each group of students to determine the percentage of agreement for the performance criteria of all locomotor and object control skills. Agreements of 98.6, 94.1, and 97.8% were found for the AD, MD, and TD groups respectively on the *TGMD-2* and 93.5, 88.5, and 86.7% on *PE-Metrics*.

3.3 Results

All analyses were performed using SPSS version 18.0 with alpha set at .05, with the exception of the multivariate analyses of variance (MANOVA) where a Bonferroni adjustment was used to reduce the likelihood of committing a Type 1 error. Effect sizes of 0.2, 0.5, and 0.8 were considered small, moderate, and strong for this study (Thomas, Nelson, & Silverman, 2011).

Several statistical analyses were initially conducted to ensure that differences in movement performance among groups were not influenced by the order in which the assessments were administered or the age of the students. Four independent samples t-tests were conducted with the order of assessments as the independent variable and the raw locomotor and object control subtest scores of the *TGMD-2* and *PE-Metrics* as the dependent variables. Performance differences were not revealed for the raw locomotor [$t(40) = .88$, $p = .38$] and object control [$t(40) = 1.84$, $p = .07$] subtest scores of the *TGMD-2*, as well as the raw locomotor [$t(40) = .89$, $p = .38$] and object control [$t(40) =$

.95, p = .35] subtest scores of the *PE-Metrics*. An analysis of variance (ANOVA) was then used to determine whether the age of the students differed between the AD, MD, and TD group. Results were not statistically significant, $F(2, 35) = 2.03$, $p = .15$, meaning that these variables did not have to be controlled for in subsequent analyses.

Correlation coefficients were computed for the locomotor and object control skills on the *TGMD-2* and *PE-Metrics* to examine significant relationships and provide support for the use of the *PE-Metrics*. The results of the correlational analyses presented in Table 5 show that the horizontal jump, jump forward, and jumping and landing combination were statistically related, with the coefficients being greater than or equal to .38. The locomotor sequence, jump forward, and jumping and landing combination were also significantly related with coefficients ranging from .43 to .48. Table 6 shows that the stationary dribble is significantly correlated with the dribble with one hand and jog, as would be expected. These findings provide support for the use of MANOVAs to examine differences in performance amongst the three groups on the *TGMD-2* and *PE-Metrics*. As well, these correlations illustrate the association between performance on static and dynamic skills that are variations of the same skill, but with increasing complexity.

Differences in movement performance on the *TGMD-2* were examined among the three groups using raw scores. A one-way MANOVA was performed to determine differences in the overall performance of locomotor and object control skills on the *TGMD-2* among students in the AD, MD, and TD group. Significant differences were found among the three groups on the dependent variables, Wilks's $\Lambda = .67$, $F(4, 68) = 3.78$, $p = .008$. The multivariate η^2 based on Wilks's Λ was small, .18. Tables 7 and 8

Table 5

Pearson correlation coefficients for locomotor skills of the TGMD-2 and PE-Metrics

	1	2	3	4	5	6	7	8	9	10	11
1. Run	-										
2. Gallop	.136	-									
3. Hop	.321*	.566**	-								
4. Leap	.172	.146	.297	-							
5. Horizontal jump	.253	.196	.283	.447**	-						
6. Slide	.234	.565**	.506**	.136	.180	-					
7. Galloping	.062	.409**	.371*	.353*	.059	.162	-				
8. Jump forward	.391*	.313*	.494**	.350*	.524**	.235	.251	-			
9. Jumping and landing combination	.229	.482**	.440**	.471**	.381*	.290	.560**	.500**	-		
10. Locomotor sequence	.130	.345*	.323*	.245	.280	.144	.367*	.431**	.480**	-	
11. Skipping	.251	.102	.388*	.519**	.521**	.118	.208	.498**	.471**	.535**	-

* $p < .05$, ** $p < .01$ (two-tailed)

Table 6

Pearson correlation coefficients for object control skills of the TGMD-2 and PE-Metrics

	1	2	3	4	5	6	7	8	9	10
1. Striking a stationary ball	-									
2. Stationary dribble	.243	-								
3. Catch	.141	.196	-							
4. Kick	-.130	.146	.229	-						
5. Overhand throw	.448**	.479**	.476**	.230	-					
6. Underhand roll	-.109	.213	.297	.356*	.254	-				
7. Approach and kick a ball	.089	.313*	.117	-.202	.171	.221	-			
8. Dribble with hand and jog	.298	.530**	.406**	.114	.306*	.198	.259	-		
9. Overhand catching	.141	.429**	.273	.098	.127	.302	.210	.728**	-	
10. Striking with paddle	.287	.515**	.367*	.291	.441**	.134	.324*	.654**	.572**	-

* $p < .05$, ** $p < .01$ (two-tailed)

Table 7

Group descriptive statistics for raw scores, standard scores, and percentiles of each subtest of the TGMD-2

	AD (n = 8)	MD (n = 12)	TD (n = 18)
Locomotor subtest			
Range of raw scores	27.00 – 42.00	8.00 – 44.00	25.00 – 46.00
Raw score	34.63(6.57)	30.17(9.44)	35.56(5.00)
Standard score	5.75(2.71)	4.67(2.67)	6.39(2.06)
Percentile	14.38(13.66)	9.33(13.70)	15.44(16.89)
Object control subtest			
Range of raw scores	30.00 – 46.00	20.00 – 40.00	32.00 – 47.00
Raw score	36.75(5.63)[a]	30.67(6.54)[a,b]	38.39(4.03)[b]
Standard score	7.13(2.30)	4.50(2.15)	7.78(2.49)
Percentile	22.13(21.39)	6.92(8.00)	28.28(24.70)

AD = Academic difficulties; MD = Movement difficulties; TD = Typically developing

Note: Means and (standard deviations) are reported for all scores and percentiles, with the exception of the range of raw scores for each subtest

[a] $p < .05$, [b] $p = .001$

Table 8

Group means and (standard deviations) for raw scores on each skill of the locomotor and object control subtest of the TGMD-2

	AD (*n* = 8)	MD (*n* = 12)	TD (*n* = 18)
Locomotor subtest (48)	34.63(6.57)	30.17(9.44)	35.56(5.00)
Run (8)	7.13(1.46)	6.67(1.61)	6.61(1.38)
Gallop (8)	5.63(2.00)	5.33(2.06)	6.28(1.32)
Hop (10)	6.63(1.19)	4.83(2.44)	6.83(1.76)
Leap (6)	4.75(1.04)	4.50(1.31)	5.33(1.14)
Horizontal jump (8)	6.75(1.39)	5.55(2.38)	6.61(1.58)
Slide (8)	3.75(2.25)	3.83(2.98)	3.89(2.03)
Object control subtest (48)	36.75(5.63)	30.67(6.54)	38.39(4.03)
Striking a stationary ball (10)	7.38(2.39)	8.17(1.90)	8.78(1.48)
Stationary dribble (8)	5.75(1.83)	2.92(2.27)	6.17(1.38)
Catch (6)	5.63(1.06)	4.92(1.00)	5.89(0.47)
Kick (8)	7.13(1.46)	6.17(1.19)	6.17(1.54)
Overhand throw (8)	5.38(2.13)	4.50(2.68)	6.22(1.48)
Underhand roll (8)	5.50(1.69)	4.00(1.81)	5.17(1.86)

AD = Academic difficulties; MD = Movement difficulties; TD = Typically developing

Note: The maximum score a child can obtain for each movement skill is noted in parentheses following the skill name contain the means and standard deviations on the dependent variables for the three groups.

Follow-up ANOVAs on each dependent variable were then conducted using the Tukey method. The ANOVA on the raw object control subtest scores was significant, $F(2, 35) = 8.00$, $p = .001$, $\eta^2 = .31$, while the ANOVA on the raw locomotor subtest scores was not significant, $F(2, 35) = 2.24$, $p = .12$. Post hoc analyses for the object control subtest scores consisted of conducting pairwise comparisons to determine which groups significantly differed from one another. Each pairwise comparison was tested at the .05 level divided by 2 or .025 level. The AD ($M = 36.75$, $SD = 5.63$) and TD ($M = 38.39$, $SD = 4.03$) groups demonstrated greater performance on the object control subtest than the MD ($M = 30.67$, $SD = 6.54$) group. The AD and TD groups were not significantly different from each other.

A second MANOVA was conducted to examine between group differences in locomotor and object control subtest scores of the *PE-Metrics*. Significant differences were found for the AD, MD, and TD groups on the dependent variables, Wilks's $\Lambda = .59$, $F(4, 68) = 5.14$, $p = .001$. The strength of the relationship between groups and the subtest scores of the *PE-Metrics*, as assessed by η^2, was still small with the group accounting for 23.2% of the variance. Means and standard deviations on the dependent variables for the three groups are reported in Table 9. The ANOVA results were significant for both the raw locomotor [$F(2, 35) = 6.25$, $p = .005$, $\eta^2 = .26$] and object control [$F(2, 35) = 8.38$, $p = .001$, $\eta^2 = .32$] subtest scores. Pairwise comparisons demonstrated that the AD ($M = 45.38$, $SD = 5.45$) and TD ($M = 46.17$, $SD = 5.85$) groups had greater performance on the locomotor subtest than the MD ($M = 36.17$ $SD = 11.31$) group, while the AD and TD

Table 9

Group means and (standard deviations) for raw scores on each locomotor and object control skill of the PE-Metrics

	AD (n = 8)	MD (n = 12)	TD (n = 18)
Locomotor subtest (56)	45.38(5.45)[a]	36.17(11.31)[a,b]	46.17(5.85)[b]
Galloping (8)	5.00(2.56)	5.33(1.78)	6.06(1.66)
Jump forward (24)	22.88(1.64)	17.17(6.00)	21.50(3.19)
Jumping and landing combination (8)	5.13(1.89)	4.17(1.95)	5.22(1.22)
Locomotor sequence (8)	5.13(0.64)	4.08(1.93)	5.83(1.62)
Skipping (8)	7.25(1.75)	5.91(3.30)	7.56(0.92)
Object control subtest (68)	51.00(9.62)[b]	34.92(13.20)[b]	49.61(9.00)[b]
Approach and kick a ball (24)	16.25(5.37)	15.25(4.69)	16.72(4.39)
Dribble with hand and jog (12)	8.38(2.92)	4.25(3.65)	8.67(1.97)
Overhand catching (24)	21.75(3.11)	12.67(7.44)	19.44(4.49)
Striking with paddle (8)	4.63(1.92)	2.75(1.06)	5.06(1.85)

AD = Academic difficulties; MD = Movement difficulties; TD = Typically developing

Note: The maximum score a child can obtain for each movement skill is noted in parentheses following the skill name. The maximum scores for all of the locomotor skills were summed to create a locomotor "subtest" score and all of the maximum scores for the object control skills were added for the object control "subtest" score.

[a] $p < .05$, [b] $p < .01$

groups were not significantly different from one another. Similar findings were revealed for the object control subtest where the AD (*M* = 51.00, *SD* = 9.62) and TD (*M* = 49.61, *SD* = 9.00) groups demonstrated greater performance than the MD (*M* = 34.92, *SD* = 13.20) group, but did not significantly differ from each other. Although not significant, the TD group displayed greater competence than the AD group on all comparisons except the object control subtest of the *PE-Metrics*.

3.4 Discussion

This study moved beyond previous research in terms of the assessments and the breadth and depth of the number of skills examined. As a result, it provided a more detailed understanding of the aspects impaired in the performance of various fundamental movement skills among students with AD and MD. Since approximately half of the students with AD also demonstrate some difficulties in the motor domain (Woodard & Surburg, 2001), I was interested in how they compared to students identified with MD alone. Students with AD did not demonstrate impaired performance of fundamental movement skills as expected and therefore, did not demonstrate similar levels of impairment as students with MD. Rather, students with MD demonstrated significant difficulties in the performance of locomotor (*PE-Metrics*) and object control skills (both *TGMD-2* and *PE-Metrics*) compared to students with AD and their TD peers.

Students with MD demonstrated the poorest performance on the stationary dribble, catch, overhand throw, and underhand roll on the *TGMD-2*. Similarly, their performance for the dribble with one hand and jog, overhand catch, and strike with a paddle on *PE-Metrics* was substantially lower than the other two groups. Over half of the students with MD did not demonstrate the essential elements of a static or dynamic dribble, which consisted of pushing the ball with their fingertips, contacting the ball at approximately waist height and in front of or to the outside of their foot on the preferred side. Their inability to maintain control of the ball also resulted in an inconsistent jogging speed and at times, they stopped dribbling because the ball rolled outside of the designated boundaries. Performance for catching a ball was primarily impacted by their inability to catch the ball with only their hands. For the *PE-Metrics*, 8 of 12 students with MD failed to catch the ball altogether or caught the ball and then dropped it. Since the ball is thrown slightly above their head, students often jumped to catch the ball even though the task demands did not require such action. In contrast, the ball is thrown at chest level for the *TGMD-2* and therefore, students attempted to catch the ball by trapping it against their body.

When throwing a ball overhand, 8 of 12 students did not initiate their throw using a windup and did not rotate their hip and shoulders to a point where the non-throwing side faces the wall. Rather, their movement patterns resembled ones associated with the final stages of a shot put throw. Their hips were initially square with the wall and the ball was raised to neck level and thrusted forward. For the underhand roll, students with MD tended to not take a stride forward with the foot opposite of their preferred hand, did not bend their knees, and released the ball at a height that was greater than 4 inches. However, striking a ball with a paddle was possibly the most difficult movement skill to perform as 7 of 12 students were only able to strike the ball 1 or 2 consecutive times (instead of the required 5 to be deemed competent) and 11 of 12 students moved outside of the 10 foot square 3 or more times within a 30 second period.

Given the plethora of difficulties demonstrated among students with MD for object control skills in this study, the predominant focus on ball catching performance in the literature appears just. This study examined performance of object control skills beyond catching, but still found evidence to support immature movement patterns (Utley & Astill, 2007), inefficient movement strategies (Przysucha & Maraj, 2010), and impaired aspects of movement (Sekaran et al., 2012; Van Waelvelde et al., 2004) that affected successful performance among students with MD. Students with MD also displayed considerable variability in the performance of the same movement skill across trials.

All three groups performed comparably on the locomotor subtest of the *TGMD-2,* which is incongruent with previous literature (Chia et al., 2013; Westendorp et al., 2011; Woodard & Surburg, 2001). Collectively, students across all three groups demonstrated the greatest difficulties for the gallop, hop, leap, and slide. The majority of students did not have their arms bent at waist height at takeoff for the gallop and often crossed their trailing foot in front of their lead foot throughout. Difficulties related to producing force were also apparent among students for the hop. The nonsupport leg did not swing forward in a pendular fashion to produce force, with several students holding their nonsupport leg in front of their body instead of behind. Their arms often remained stationary at their sides and did not swing forward to produce force and momentum. The tendency to not use their arms also primarily impacted performance on the leap where students did not reach forward with the arm opposite the lead foot. Students in the three groups had the greatest difficulties with the slide as they did not have their shoulders aligned with the line on the floor and were unable to demonstrate a minimum of 4 step-slide cycles to the right and left. It appears that many students demonstrate difficulties in bilateral coordination and use inefficient movement patterns.

On the other hand, differences in performance were revealed between groups for the locomotor subtest of the *PE-Metrics*. Students with MD particularly struggled with the jump forward, jumping and landing combination, and locomotor sequence compared to students with AD and their peers. Six of 12 students with MD largely failed to use their arms to produce force and momentum as they jumped forward and demonstrated difficulty simultaneously taking off and landing on 2 feet. They also struggled with executing the proper sequence of movements for the jumping and landing combination. The difficulties they experience with respect to performing sequenced movements also impacted their ability to execute smooth transitions in the locomotor sequence. Unexpectedly, students with MD demonstrated greater performance than students with AD for galloping. Students with MD had an identical average score for galloping on both assessments, whereas students with AD demonstrated worse performance for galloping on the *PE-Metrics*. Because students are required to alternate their lead foot on successive trials when galloping as part of the *PE-Metrics*, this may explain the difference in performance between assessments.

Differences in the performance of fundamental movement skills among the three groups were most apparent for skills that were of greater complexity. For instance, all students performed comparable on the locomotor subtest of the *TGMD-2*, but significant differences were revealed between students with MD and their peers on the locomotor subtest of the *PE-Metrics*. When examining the mean scores on the locomotor subtests of each assessment for the three groups, the gap in performance was greater on the *PE-*

Metrics. Raw scores obtained on the object control subtest of the *PE-Metrics* were also substantially lower for each group compared to the *TGMD-2*, meaning that students were less competent in the performance of more dynamic object control skills. Although students with MD demonstrated the greatest difficulties for a variety of fundamental movement skills, students with AD and TD peers did not demonstrate proficiency for the majority of fundamental movement skills either.

The decreasing physical activity levels of children today may be a plausible explanation for the discrepancies found in this study compared to earlier literature. Over the last several years, children have become increasingly more sedentary (Colley et al., 2011) with substantial increases reported for childhood obesity (Tremblay et al., 2010). Canada has also consistently been receiving failing grades on the Active Healthy Kids Report Cards, which assesses the physical activity of Canadian children (Active Healthy Kids Canada, 2013). It is imperative that children acquire a diverse motor repertoire that is adaptive and flexible to perform fundamental movement skills in different movement contexts (Davids, Button, & Bennett, 2008). If children are not proficient in these basic skills, they will have limited opportunities to participate in physical activities in adolescence because they will not have the prerequisite skills to be active (Clark & Metcalfe, 2002).

Fundamental movement skills are not acquired naturally through maturational processes (Clark 2005), but need to be learned, practiced, and reinforced (Goodway & Branta, 2003; Robinson & Goodway, 2009; Valentini & Rudisill, 2004). Physical education is a required area of study in Canadian school curricula and therefore, schools are a great place for students to adopt healthy habits. During early school years, instruction needs to be focused on the learning of fundamental movement skills among students in order for them to utilize these movement skills in other contexts such as extracurricular or organized activities (Clark & Metcalfe, 2002). However, most classroom teachers in Canada are responsible for instructing physical education during elementary school years rather than trained physical educators (Mandigo, 2010). Quality instruction needs to be provided for students in physical education to afford them the opportunity to work and learn at their own pace of skill development, while also receiving constructive feedback on their performance (Robinson, Kipling Webster, Wood Logan, Amarie Lucas, & Barber, 2012).

3.4.1 Limitations

As an inherent aspect of all research, there were limitations present in this study. My sample was comprised of only 8 students with AD, 12 students with MD, and 18 TD peers. As such, further investigation using a larger sample is required to determine the range of fundamental movement skills impacted among students with AD and MD and the aspects of performance impaired. As well, students with AD and MD included in this research demonstrated difficulties in various academic areas, as opposed to having a formal a diagnosis of LD or DCD. While this is a limitation, it is also the reality of school-based research since not all students that demonstrate difficulties in core academic areas receive a formal diagnosis or the appropriate services to address their difficulties in (learning and) performance.

3.4.2 Future Direction

Knowledge gained from this study was largely inconsistent with previous research, but may have shed light on a larger issue concerning children in society today. Children may not be acquiring and practicing fundamental movement skills during a critical period in their development in order to lead an active lifestyle.

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CHAPTER 4: Physical Activity and the Activity Deficit Hypothesis among Students with Academic or Movement Difficulties

Physical activity is defined as any bodily movement produced by skeletal muscles and requiring the expenditure of energy (World Health Organization, 2001). According to Health Canada guidelines, children and youth between the ages of 5 and 17 should accumulate at least 60 minutes of moderate-vigorous physical activity (MVPA) each day in order to achieve healthy growth and development (Canadian Society for Exercise Physiology [CSEP], 2011). It is also recommended that they engage in physical activity of vigorous intensity (e.g., running) for a minimum of 20 minutes at least three days per week and engage in activities that strengthen bones and muscles (e.g., jumping rope or climbing and swinging on playground equipment; CSEP, 2011).

Despite these recommendations, only 7% of Canadian children and youth accumulate 60 minutes of MVPA at least 6 days a week and only 4% engage in vigorous activity for 20 minutes at least 3 days a week (Colley et al., 2011). Of particular relevance to this study is that children who have difficulty performing movement skills may engage less in MVPA than their peers (Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996; Cairney, Hay, Faught, Corna, & Flouris, 2006; Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2010). Both children with learning disorders (LD) and developmental coordination disorder (DCD) demonstrate inconsistent movement patterns and impaired aspects of specific components of movement that contribute to their performance (e.g., Moe-Nilssen, Helbostad, Talcott, & Toennessen, 2003; Utley & Astill, 2007; Van Waelvelde, De Weerdt, De Cock, Smits-Engelsman, & Peersman, 2004), which may impact participation in various activities. The development of teaching strategies and intervention is pertinent for these children to acquire the skills they need for successful performance of fundamental movement skills and as a result, achieve the health-related benefits associated with increased participation in physical activity (CSEP, 2012).

4.1 Physical Activity among Students with (Academic or) Movement Difficulties

Accelerometers allow researchers to examine aspects of physical activity not previously measurable by self-report methods (Strath, Pfeiffer, & Whitt-Glover, 2012) by quantifying the frequency, intensity, and duration of physical activity (McClain & Tudor-Locke, 2009; Reilly et al., 2008). Collectively, studies that have used accelerometers to examine physical activity among children who demonstrate movement difficulties found they are less active compared to their peers (Silman, Cairney, Hay, Klentrou, & Faught, 2011) with significant differences in MVPA most evident among children at the extremes of the movement spectrum (Fisher et al., 2005; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). One study reported that children in the lowest quartile for movement performance averaged 27.9 minutes of MVPA each day whereas children in the highest quartile accumulated 45.7 minutes (Wrotniak et al., 2006). Although a difference of less than 18 minutes per day does not seem significant, these values mean that children with MD accumulate on average 2 hours (or 124.6 minutes) less of MVPA each week than their typically developing peers.

The presence of movement difficulties at an early age may predict physical activity levels in later life (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009) since habits formed in childhood have been shown to persist in adolescence and adulthood (Biddle, Gorely, & Stensel, 2004). No research to date has quantified physical activity levels among children with LD even though over half of these children also demonstrate movement difficulties to some degree (Westendorp, Hartman, Houwen, Smith, & Visscher, 2011; Woodard & Surburg, 2001). As a result, children with LD may also be at greater risk for secondary health consequences associated with inactivity than their typically developing peers. This underscores the necessity for early intervention among children that demonstrate difficulties in the motor domain to help them develop the skills necessary to engage in increased physical activity.

4.2 The Activity Deficit Hypothesis

Fundamental movement skills need to be learned, practiced, and reinforced (Goodway & Branta, 2003; Robinson & Goodway, 2009; Valentini & Rudisill, 2004). Typically developing children develop proficiency in the performance of fundamental movement skills with age and acquire increased proficiency in their ability to utilize these skills in different activities and across a variety of contexts (Wall, 1982, 2004). However, children with DCD may not have yet mastered these basic skills and therefore experience greater difficulties participating in the same competitive and demanding activities as their same-aged peers (Wall, 2004). These differences in performance for children with DCD and their typically developing peers are hypothesized to widen with increasing age and has been referred to as the developmental skill-learning gap (Wall, 1982, 2004).

If children are not proficient in the performance of fundament movement skills, they may have limited opportunities to participate in (physical) activities and organized games that require the use of more advanced or sport-specific skills (Clark & Metcalfe, 2002). This notion is referred to as the activity deficit hypothesis; the belief that children with movement difficulties are less active than their typically developing peers of the same age (Bar-Or, 1983; Bouffard et al., 1996). The activity deficit demonstrated among children with DCD is believed to grow larger as their activities become more complex (Wall, 2004). This hypothesis has traditionally been examined through subjectively measured participation patterns for a variety of children's activities. These activities are generally classified as being either structured or unstructured. Structured activities include rules and goals with the presence of a coach, instructor, or leader, whereas unstructured activities may involve little or no planning and are often initiated independently (King et al., 2004).

Students at risk for DCD (*r*DCD) aged 6 to 14 have been found to participate less in structured, unstructured, and vigorous activities compared to their peers (Bouffard et al., 1996; Cairney et al., 2006). This may be partly attributed to exclusion or withdrawal experienced among these students, resulting in more time spent alone or watching other children play during opportunities to be physically active such as recess (Bouffard et al., 2006; Smyth & Anderson, 2000). The presence of movement difficulties also affects students' participation in out of school activities, particularly recreational, physical, social, and skill-based activities (Fong et al, 2011; Jarus, Lourie-Gelberg, Engel-Yeger & Bart, 2011).

Longitudinal research has found the gap in physical activity participation among students at *r*DCD and their typically developing peers remained constant between 9 and 12 years of age (Cairney et al., 2010). When engagement in school playground activities was examined among students at *r*DCD, 28% did not partake in more than half of the playground activities determined culturally normative for their age and gender (Watkinson et al., 2001). These findings suggest that students at *r*DCD may not take advantage of opportunities to practice and refine the fundamental movement skills needed to acquire more advanced or sport-specific skills.

When accelerometers were used to examine the relationship between movement performance and participation in physical activity, only a weak correlation was found for the percentage of time spent in MVPA among children aged 3 to 5 years (Fisher et al., 2005). However, small correlations were found between movement performance and the percentage of time spent in sedentary, moderate, and MVPA for children 8 to 10 years of age (Wrotniak et al., 2006). It appears that in early childhood, the association between movement performance and physical activity may not be as pronounced as in later years. Because young children are in the process of acquiring fundamental movement skills, this deficit may not be evident until early school years when children are challenged to meet increasing demands and expectations placed on them (Wall, 2004).

Participation in school-based activities, sports clubs, and general play are thought to be most prevalent during childhood (Hills, King, & Armstrong, 2007). As a child enters adolescence, participation in physical activity seems to be displaced by other activities and interests. However, significant differences were not found between adolescents at *r*DCD and their typically developing peers for average energy expenditure and step counts per day (Baerg et al., 2011). Comparatively, a longitudinal study reported greater participation in MVPA among typically developing boys compared to boys at *r*DCD, but no differences between typically developing girls and girls at *r*DCD (Green et al., 2011). Physical activity levels remained constant among girls at *r*DCD between the ages of 7 and 12, suggesting that girls in general may already be less active.

Evidence of the developmental skill-learning gap hypothesis has been demonstrated by the array of studies that have explored the activity deficit hypothesis. However, all of the studies that examined movement performance relative to physical activity used assessments such as the *Movement Assessment Battery for Children* (*MABC-2*) or *Bruininks-Oseretsky Test of Motor Proficiency*, which may not actually measure the movement skills used by students in a variety of physical activities. These assessments were also largely used to identify children with or at *r*DCD, with no subsequent assessments administered to examine movement performance. Therefore, this study used the *Test of Gross Motor Development* (*TGMD-2*; Ulrich, 2000) to examine the performance of fundamental movement skills among students relative to their engagement in physical activity. Congruent with the literature presented, this study focused on students who were specifically identified as having demonstrable difficulties in reading, writing, math, and/or physical education.

The first objective of this study was to quantify physical activity levels using accelerometers among students who demonstrated academic difficulties (AD) that spanned into the motor domain and those with movement difficulties (MD) only, compared to their typically developing peers. The activity deficit hypothesis was then explored collectively amongst students by examining the relationship between their performance of fundamental movement skills and accelerometer-based estimates of physical activity. It was hypothesized that students with more proficient movement skills would demonstrate greater levels of physical activity because of their ability to use and practice these skills in various activities. This means typically developing students should spend more time engaged in MVPA compared to students with AD and MD.

4.3 Methods

4.3.1 Participants

Forty-two students between 7 and 10 years of age were recruited from three elementary schools that were close in proximity and of comparable socioeconomic status in the Regina Public School system. Learning resource teachers at each school referred students with AD who were currently receiving additional instruction and services, while the primary researcher was involved in physical education classes prior to the study to help classroom teachers identify students with MD through observation. Particular attention was paid to those students who demonstrated difficulty with ball and balance skills as well as the ability to run smoothly and stop with control. Students with sensory deficits, cognitive impairments, or other developmental disabilities (e.g., autism) were not recruited for participation.

Students identified as having AD or MD were given a consent form to take home in order to obtain approval from their parents or guardians and their assent. Once consent was provided, students with AD and MD were administered the *MABC-2* (Henderson, Sugden, & Barnett, 2007) by two researchers to determine their degree of motor impairment and confirm inclusion criteria for each group. Twelve students with AD were initially identified however, only 8 of those students also scored below the 16th percentile on the *MABC-2* and were considered to have difficulties spanning across multiple academic areas. The 4 students with AD who did not demonstrate difficulties extending to the motor domain were not included in our analyses resulting in a sample of 38.

A typically developing (TD) group was established by the primary researcher and the principal or learning resource teacher at each school in order to make comparisons with respect to physical activity levels among students with AD and MD. Typically developing students with birthdates approximately 2 months from that of a student with AD or MD, and was of the same sex, were identified as being potential participants. Informed consent forms were sent home with these students to obtain parental consent and student assent.

Comparisons were made among 8 students with AD (M_{age} = 9.75 years, *SD* = 0.34), 12 students with MD (M_{age} = 8.90 years, *SD* = 0.27), and 18 TD peers (M_{age} = 9.12 years, *SD* = 0.22). There were 4 boys and 4 girls in the AD group (8 to 10 years), 8 boys and 4 girls in the MD group (7 to 10 years), and 12 boys and 6 girls in the TD group (7 to 10 years). Students who demonstrated characteristics associated with ADHD were included in this study since they represent the true range of difficulties experienced by students with academic and movement difficulties (Dewey, Kaplan, Crawford, & Wilson, 2002; Iversen, Berg, Ellertsen, & Tonnessen, 2005; Jongmans, Smits-Engelsman, & Schoemaker, 2003; Kadesjö & Gillberg, 1999; Watemberg, Waiserberg, Zuk, & Lerman-Sagie, 2007). However, there was only 1 student with AD that had a formal diagnosis of ADHD.

4.3.2 Measures

The movement performance of each student was assessed using the *TGMD-2* (Ulrich, 2000); a standardized assessment for children 3 to 10 years that examines movement patterns needed for successful performance of fundamental movement skills. The assessment consists of 2 subtests comprised of 6 movement skills each. The locomotor subtest includes the run, gallop, hop, leap, horizontal jump, and slide and the object control subtest is comprised of the strike, dribble, catch, kick, throw, and roll. Each skill is comprised of 3 to 5 performance criteria that are required for mastery of that skill. Scoring focuses on the presence (1) or absence (0) of each performance criteria that is measured over two trials of each task. Composite raw scores for each subtest range from 0 to 48, where higher scores indicate greater movement performance. To obtain an overview of a student's overall performance on particular skills, a gross motor quotient (GMQ) can also be derived from the sum of the subtest standard scores.

The *TGMD-2* provides a developmental framework to examine movement performance among students and focuses on the performance of functional skills that may be performed in physical education. The assessment utilizes typical physical education or playground equipment and administration occurs in a familiar setting for students such as a gymnasium or school playground. These factors contribute to the ecological validity of the *TGMD-2*. The internal consistency, test–retest, and inter-rater reliability of the *TGMD-2* varies between .85 and .98 for both subtests and the gross motor quotient. All items in the *TGMD-2* are considered "good," with discrimination indexes ranging from .38 to .58. Criterion-predictive validity was assessed between the *TGMD-2* subtests and the *Comprehensive Scales of Student Abilities*. Partial correlations were .63 for the locomotor and .41 for the object control subtest. Results from the confirmatory factor analysis showed that the skills representing each subtest are valid indicators of locomotor and object control abilities (χ^2 = 280.3; GFI = .96; AGFI = .95).

Physical activity levels were quantified for each student using GT3X ActiGraph accelerometers (ActiGraph, 2012). These accelerometers measure the frequency and intensity of the body's acceleration during movement in three directions (vertical, horizontal, and lateral). They are small, lightweight devices typically worn around the waist on an adjustable belt to measure whole body movements (Nilsson, Ekelund, Yngve, & Sjöström, 2002; Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). Seven day monitoring periods have routinely been used to obtain reliable estimates of children's daily physical activity, with at least one weekend day included (Trost, Pate, Freedson, Sallis, & Taylor, 2000). Younger children tend to display higher levels of MVPA on weekends compared to weekdays, which may be the result of regimented schedules on school days. A minimum of 10-hour days of wearing time on at least 4 days constitutes a valid data set (Matthews, Hagströmer, Pober, & Bowles, 2012; Trost, McIver, & Pate, 2005). However, shorter monitoring periods may be used for quantifying physical activity in sedentary populations, especially those with disabilities (Kim & Yun, 2009; Tudor-Locke & Myers, 2001). Reliable and valid estimates of physical activity have been found using 2 weekdays of wear time for youth with disabilities (Jeong, 2012). Both monitoring protocols were used for the analyses, with differing numbers of students for each. There were 24 students who met the protocol for 3 weekdays and 1 weekend day of wear time and 35 students who met the protocol for 2 weekdays.

As one moves, the acceleration signal from the accelerometer is digitized and generates "activity counts," which are summed over a pre-determined epoch length or sampling interval. A 5 second epoch was chosen for this study based on previous literature that suggests it is most suitable for capturing short bouts of MVPA among school-aged children (Baquet, Stratton, Van Praagh, & Berthoin, 2007; Nilsson et al., 2002) and because it can be summed to create 10, 15, or 30 second epochs for comparison to other studies (Strath et al., 2012). These activity counts must be entered into a regression-based model in order to make sense of the data and estimate time spent at each of the physical activity intensities.

Cut points are used to determine whether children engaged in sedentary, light, moderate, and vigorous physical activity during the monitoring period. The use of cut points developed for free living activities are essential since these represent the broad repertoire of activities that children typically perform (Freedson, Pober, & Janz, 2005). As such, the Puyua (2002) cut points were used for calculation of the different physical activity intensities among students. Counts per minute that ranged from 0 to 799 were indicative of sedentary behaviour, 800 to 3199 were associated with light activity, 3200 to 8199 with moderate activity, and 8200 or more was categorized as being of vigorous activity. The majority of cut points developed for children do not include metabolic equivalents (METs); however METs do provide valuable information for comparison with other studies. The Freedson, Pober, and Janz (2005) equation was used to compute METs where <1.5 METs were considered sedentary, 1.5 METs was light, 3 METs was moderate, and 6 METs was vigorous.

4.3.3 Procedure

All procedures were carried out in accordance with the University of Regina Research Ethics Board and the Regina Public School Board. Administration of the *TGMD-2* and physical activity monitoring occurred over the months of May and June. The primary researcher followed the research protocol in the administration of the *TGMD-2*. A demonstration for each skill was provided along with verbal instructions, followed by a practice trial. A second demonstration was given if the student did not understand the task following the practice trial. For 2 of the 3 elementary schools, students were administered the *TGMD-2* in the school gymnasium. Due to a lack of gym availability at the third school, students were assessed outdoors on a tarmac during morning school hours and not including recess. The movement performance for each student was videotaped by the second researcher and subsequently scored. A trained research assistant who was unaware of the age and group of each student scored the assessments. To ensure accuracy of scoring, the primary researcher scored 30% of both assessments for each group of students to determine the percentage of agreement for the performance criteria of all locomotor and object control skills. Agreement of 98.6, 94.1, and 97.8% was found for the AD, MD, and TD groups respectively on the *TGMD-2*.

The physical activity levels of each student were then monitored over 7 consecutive days using GT3X accelerometers. All accelerometers were pre-programmed individually for each student's age, gender, birth date, height, and weight. Students were given an accelerometer at school that was attached to a flexible waist belt with verbal instructions on how to wear and care for the device. Their parents or guardians were also provided with written instructions for wear and care to assist their child in meeting the research protocol, as well as a 7-day log to record their child's wakeup times, when the accelerometer was removed/replaced (bathing, swimming, or other reasons), and bedtime. Activity logs were largely used to aid in wear time validation, which is the process of distinguishing between a student's wear time versus non-wear time over the course of a day. Students were asked to wear the accelerometer on the right hip each day from morning to night for a minimum of 10 hours (600 minutes). The researchers collected the accelerometers and activity logs at each school following the last day of monitoring and the data was downloaded onto a computer and analyzed using ActiLife 6.

4.4 Results

All analyses were performed using SPSS version 18.0 with alpha set at .05, with an effect size of 0.2, 0.5, and 0.8 considered small, moderate, and strong for this study (Thomas, Nelson, & Silverman, 2011). Two separate sets of analyses were conducted to examine differences in physical activity among groups for each of the monitoring protocols. The first set of analyses were performed using 24 of 38 students who wore the accelerometer for 3 weekdays and 1 weekend day for at least 10 hours per day. The second set of analyses included 35 of 38 students who wore the accelerometer for 2 weekdays for a minimum of 10 hours per day.

Means and standard deviations for age, height, weight, and body mass index (BMI) are reported in Table 10 for students who met each of the monitoring protocols. Several analyses of variance (ANOVA) were performed to examine differences in anthropometric measures between students with AD, MD, and their TD peers. Students in each group who wore the accelerometer for a total of 4 days did not differ in terms of their age [$F(2, 21) = 2.02$, $p = .16$], height [$F(2, 21) = 2.70$, $p = .09$], weight [$F(2, 21) = .36$, $p = .70$], and BMI [$F(2, 21) = .04$, $p = .96$]. Significant differences were also not revealed for age [$F(2, 32) = 2.34$, $p = .11$], height [$F(2, 32) = 1.63$, $p = .21$], weight [$F(2, 32) = .57$, $p = .57$], and BMI [$F(2, 32) = .85$, $p = .44$] amongst the three groups of students who met the monitoring protocol for 2 weekdays.

Independent samples t-tests were then performed by group to examine differences among students who met the monitoring protocol for 4 days versus 2 days. The monitoring protocol (4 days or 2 days) was the independent variable, with age and raw scores obtained on the *TGMD-2* as the dependent variables. Collectively, students with

Table 10

Means and (standard deviations) for anthropometric measurements of students in each group and the total sample

	AD (n = 6)	MD (n = 8)	TD (n = 10)	Total Sample (n = 24)
4 days				
Age (years)	9.53(0.90)	8.64(0.77)	9.28(0.94)	9.13(0.91)
Weight (lbs)	77.67(26.70)	69.13(22.79)	77.70(21.47)	74.83(22.59)
Height (inches)	55.03(3.39)	51.76(2.92)	55.50(4.08)	54.13(3.82)
BMI (lbs/inches^2)	17.67(4.12)	17.88(4.41)	17.39(2.68)	17.62(3.53)
	AD (n = 8)	MD (n = 12)	TD (n = 15)	Total Sample (n = 35)
2 weekdays				
Age (years)	9.74(0.87)	8.89(0.95)	8.99(0.91)	9.13(0.95)
Weight (lbs)	84.00(30.95)	77.00 (28.72)	72.07(19.34)	76.49(25.30)
Height (inches)	56.00(3.46)	52.91(3.81)	54.19(3.88)	54.17(3.83)
BMI (lbs/inches^2)	18.40(4.85)	18.84(4.80)	16.95(2.32)	17.93(3.91)

AD = Academic difficulties; MD = Movement difficulties; TD = Typically developing

Note: Descriptive statistics for 4 days were computed based on accelerometer data from 3 weekdays and 1 weekend day for each student.

AD did not differ for age [$t(6) = 1.19$, $p = .28$] and demonstrated comparable performance on the locomotor [$t(6) = 1.26$, $p = .25$] and object control subtest [$t(6) = 1.29$, $p = .24$]. Significant differences were not found for students within the MD group for age [$t(10) = 1.34$, $p = .21$] and scores obtained on the locomotor subtest [$t(10) = .42$, $p = .69$] and object control subtest [$t(10) = 1.10$, $p = .30$], as well as students in the TD group for age [$t(13) = 1.91$, $p = .08$] and scores obtained on the locomotor [$t(13) = .00$, $p = 1.00$] and object control subtest [$t(13) = 1.27$, $p = .23$].

4.4.1 Physical Activity

Descriptive statistics of physical activity levels for students who met the 4 day monitoring protocol are reported in Table 11. Differences in physical activity between students with AD, MD, and TD peers were examined using ANOVA. Significant differences were not revealed between the three groups for METs [$F(2, 21) = 2.25$, $p = .13$] or minutes spent in sedentary [$F(2, 21) = 0.97$, $p = .39$], light [$F(2, 21) = 1.92$, $p = .17$], moderate [$F(2, 21) = 2.32$, $p = .12$], vigorous [$F(2, 21) = 2.20$, $p = .14$], and MVPA [$F(2, 21) = 2.88$, $p = .08$]. Results were also not statistically significant for the percentage of time spent in sedentary [$F(2, 21) = 2.61$, $p = 1.00$], light [$F(2, 21) = 1.54$, $p = .24$], moderate [$F(2, 21) = 2.20$, $p = .14$], vigorous [$F(2, 21) = 2.40$, $p = .12$], and MVPA [$F(2, 21) = 2.83$, $p = .08$].

Different results were produced when students who met the 2 day monitoring protocol were included in the analyses (see Table 12). Results from the ANOVAs did not reveal significant differences between the three groups for minutes spent in sedentary [$F(2, 32) = 0.40$, $p = .68$], light [$F(2, 32) = 2.61$, $p = .09$], and vigorous [$F(2, 32) = 2.59$, $p = .09$] physical activity or the percentage of time spent in sedentary [$F(2, 32) = 2.80$, p

Table 11

Group means and (standard deviations) for METs and the different intensities of physical activity based on accelerometer data for 3 weekdays and 1 weekend day

	AD (n = 6)	MD (n = 8)	TD (n = 10)
METs	2.03(0.32)	1.96(0.15)	2.23(0.32)
Sedentary			
Range of minutes	562.53 – 744.95	579.10 – 763.94	557.48 – 777.61
Time (minutes)	669.91(63.87)	641.46(60.73)	623.33(67.05)
Range of percentages	73.21 – 85.92	78.16 – 86.67	69.36 – 82.43
Percentage of time	80.76(5.46)	81.88(2.88)	77.46(4.42)
Light			
Range of minutes	89.97 – 154.88	76.06 – 127.67	101.78 – 164.76
Time (minutes)	119.22(24.67)	108.36(16.19)	127.55(21.33)
Range of percentages	11.56 – 18.81	9.65 – 16.47	13.95 – 20.16
Percentage of time	14.31(3.29)	13.99(2.32)	15.93(2.12)
Moderate			
Range of minutes	19.38 – 58.78	21.81 – 39.31	23.35 – 82.69
Time (minutes)	37.04(16.74)	29.37(6.16)	46.52(21.91)
Range of percentages	2.35 – 7.32	2.98 – 5.32	3.25 – 10.16
Percentage of time	4.46(2.14)	3.82(0.81)	5.80(2.58)
Vigorous			
Range of minutes	0.24 – 9.01	0.74 – 5.15	0.76 – 15.95
Time (minutes)	3.96(3.49)	2.43(1.56)	6.27(5.19)
Range of percentages	0.03 – 1.03	0.11 – 0.70	0.08 – 1.91
Percentage of time	0.47(0.41)	0.32(0.21)	0.82(0.67)
Moderate to Vigorous			
Range of minutes	19.61 – 65.40	22.54 – 42.53	26.90 – 92.28
Time (minutes)	41.00(18.99)	31.80(6.55)	52.80(23.92)
Range of percentages	2.49 – 7.98	3.21 – 5.76	3.38 – 11.67
Percentage of time	4.93(2.39)	4.14(0.85)	6.61(2.85)

AD = Academic difficulties; MD = Movement difficulties; TD = Typically developing

Note: No significant differences were found between groups for METs and the time and percentage of time spent in the different physical activity intensities.

Table 12

Group means and (standard deviations) for METs and the different intensities of physical activity based on accelerometer data for 2 weekdays

	AD (n = 8)	MD (n = 12)	TD (n = 15)
METs	2.02(0.28)	1.96(0.20)*	2.23(0.32)*
Sedentary			
Range of minutes	498.72 – 744.95	503.54 – 763.94	518.58 – 777.61
Time (minutes)	637.32(83.85)	617.24(68.80)	609.93(64.19)
Range of percentages	73.21 – 85.92	77.81 – 88.80	69.36 – 82.90
Percentage of time	80.02(5.18)	81.81(3.47)	77.97(4.18)
Light			
Range of minutes	89.97 – 154.88	65.13 – 127.67	90.25 – 164.76
Time (minutes)	119.90(24.89)	104.52(18.41)	122.18(20.44)
Range of percentages	11.56 – 21.81	8.89 – 18.06	13.05 – 20.16
Percentage of time	15.17(3.87)	14.04(2.75)	15.66(2.00)
Moderate			
Range of minutes	19.38 – 58.78	16.97 – 39.79	23.35 – 82.69
Time (minutes)	35.19(14.77)	28.23(7.54)*	43.27(19.19)*
Range of percentages	2.35 – 7.32	2.25 – 5.75	3.25 – 10.16
Percentage of time	4.44(1.83)	3.80(1.03)	5.53(2.28)
Vigorous			
Range of minutes	0.24 – 9.01	0.38 – 5.19	0.76 – 21.79
Time (minutes)	3.14(3.32)	2.55(1.72)	6.28(6.24)
Range of percentages	0.03 – 1.03	0.05 – 0.75	0.08 – 3.04
Percentage of time	0.38(0.39)	0.35(0.24)	0.84(0.84)
Moderate to Vigorous			
Range of minutes	19.61 – 65.40	17.17 – 43.96	26.90 – 92.28
Time (minutes)	38.32(16.98)	30.79(8.42)*	49.55(21.93)*
Range of percentages	2.49 – 7.98	2.30 – 6.38	3.38 – 11.67
Percentage of time	4.81(2.05)	4.15(1.16)*	6.36(2.68)*

AD = Academic difficulties; MD = Movement difficulties; TD = Typically developing

* $p < .05$

= .08], light [$F(2, 32) = 1.17$, $p = .32$], moderate [$F(2, 32) = 3.06$, $p = .06$], and vigorous [$F(2, 32) = 2.65$, $p = .09$] physical activity. However, the three groups were statistically different for METs [$F(2, 32) = 3.61$, $p = .04$], the time in minutes spent in moderate [$F(2, 32) = 3.33$, $p = .049$, partial $\eta^2 = .17$] and MPVA [$F(2, 32) = 4.03$, $p = .03$, partial $\eta^2 = .20$], as well as the percentage of time spent in MVPA [$F(2, 32) = 3.82$, $p = .03$, partial $\eta^2 = .19$].

Students in the AD and TD groups demonstrated equivalent METs ($M_{AD} = 2.02$, $SD = .10$; $M_{TD} = 2.32$, $SD = .07$), amounts of time in moderate ($M_{AD} = 35.19$, $SD = 14.78$; $M_{TD} = 43.27$, $SD = 19.19$) and MVPA ($M_{AD} = 38.32$, $SD = 16.98$; $M_{TD} = 49.55$, $SD = 21.93$), and percentage of time in MVPA ($M_{AD} = 4.81$, $SD = 2.05$; $M_{TD} = 6.36$, $SD = 2.68$). In contrast, students with MD had significantly lower METs ($M = 1.96$, $SD = .08$), time engaged in moderate ($M = 28.23$, $SD = 7.54$) and MVPA ($M = 30.79$, $SD = 8.42$), and a lower percentage of time in MVPA ($M = 4.15$, $SD = 1.16$) than their TD peers.

Comparisons of students' physical activity were made relative to Health Canada guidelines using the 24 students who met the 4 day monitoring protocol, since vigorous activity needs to be quantified for a minimum of 3 days. Only 5 of 24 students accumulated 60 minutes of MVPA per day on average over the monitoring period. One student with AD met the Health Canada physical activity guidelines as well as 4 TD peers. There were no students within this sample who averaged 20 minutes of vigorous activity each day for at least 3 days. The amount of time students spent in this intensity of physical activity was quite variable, ranging from 0.24 to 15.95 minutes per day. These findings are not unusual given that Canada has consistently received failing grades due to the vast majority of Canadian children not meeting our national physical activity guidelines (Active Healthy Kids Canada, 2013). However, it should be noted that students in the TD group tended to spend greater amounts of time in vigorous activity compared to students in the AD and MD groups.

4.4.2 The Activity Deficit Hypothesis

To determine whether there was an association between students' performance on the different components of the *TGMD-2* and their physical activity levels, Pearson correlations were conducted based on the 35 students who wore the accelerometer for 2 weekdays. Correlation coefficients were computed for the raw locomotor and object control subtest scores on the *TGMD-2* and the time (minutes and percentage) spent in the different physical activity intensities. The results of the correlational analyses are presented in Table 13.

The time spent in the different physical activity intensities was most often significantly and positively correlated with students' performance on the object control subtest compared to the locomotor subtest, with coefficients ranging from .413 to .505. Two small (but significant correlations) were found for the time students spent in moderate and MVPA and their performance on the locomotor subtest. This means that students' performance for locomotor and object control skills was higher when their time spent in more physically demanding activities was greater.

The activity deficit hypothesis was further supported when performance on the *TGMD-2* was examined relative to the percentage of time spent in the different physical activity intensities. The percentage of time spent in physical activity was calculated relative to each student's wear time and therefore, provides a better indication of the relationship between movement performance and engagement in physical activity.

Table 13

Pearson correlation coefficients for the different physical activity intensities and subtests of the TGMD-2

	Locomotor subtest	Object control subtest
Time in minutes		
Sedentary	.202	-.294
Light	.148	.505**
Moderate	.340*	.440**
Vigorous	.262	.413*
Moderate to vigorous	.359*	.482**
Percentage of time		
Sedentary	-.159	-.586**
Light	-.020	.510**
Moderate	.312	.475**
Vigorous	.238	.401*
Moderate to vigorous	.329	.512**

* $p < .05$, ** $p < .01$ (two-tailed)

Note: Pearson correlation coefficients were calculated based on the 35 students that met monitoring protocol for at least 2 weekdays.

Students' raw scores on the object control subtest were significantly associated with all intensities of physical activity. All of these relationships were positive and relatively moderate (.401 to .512) except for the percentage of time engaged in sedentary activities, which was negative (r = -.586). This indicates that students' performance on object control skills decreases as their percentage of time in sedentary activities increases. No significant relationships were found between the locomotor subtest and the percentage of time in the different physical activity intensities.

4.5 Discussion

The physical activity results found in this study both contradict and complement the literature depending on which physical activity monitoring protocol was used. This may be attributed to the different samples sizes associated with each monitoring protocol (24 students compared to 35 students). Significant differences were not found among students with AD, MD, and their TD peers for the time and percentage of time spent in sedentary, light, moderate, vigorous, and MVPA based on 4 days of wear time. However, significant differences were revealed between students with MD and their TD peers based on 2 days of wear time, which is consistent with previous research (Silman et al., 2011; Wrotniak et al., 2006). Students with MD averaged nearly 20 minutes less each day in MVPA compared to their same-aged peers. This equates to a difference of over 2 hours per week. Typically developing students tended to participate in fewer sedentary activities and more light, moderate, vigorous, and MVPA compared to students with AD as well, although the results were not statistically significant. As noted previously, it appears that differences in physical activity levels are most apparent at the extremes of the movement distribution (Fisher et al., 2005; Wrotniak et al., 2006).

Approximately 21% of students in the sample averaged 60 minutes of MVPA per day over the course of a week. Only 1 of these students was 7 years of age, while the remaining 4 students were 8 years old. Of the students who met the Health Canada recommendations for physical activity, the amount of time spent in MVPA ranged from 60.13 to 92.28 minutes. The percentage found in this study is higher than the 7% reported from the Canadian Health Measures Survey (Colley et al., 2011); however, that survey quantified levels of physical activity levels for children and youth 6 to 19 years of age. Adolescents tend to be less physically active than children irrespective of MD (Baerg et al., 2011). As such, this may explain the low percentage of children and youth who accumulated 60 minutes of MVPA each day in the national survey. Incongruent results were also found for engagement in vigorous physical activity, as no students in my sample accumulated 20 minutes on at least 3 days of the week. However, the use of different cut points to estimate the time spent in varying intensities of physical activity makes it challenging to compare the results of studies directly.

These findings complement previous literature that has examined movement performance relative to participation in physical activity among students with MD using observational or self-report methods (Bouffard et al., 1996; Cairney et al., 2006; Cairney et al., 2010; Smyth & Anderson, 2000). Students with MD were significantly less active than TD students of the same age. However, the results of this study also demonstrated that few TD students engaged in sufficient levels of physical activity, which is in line with the percentage of Canadian children and youth who are meeting these National guidelines (Colley et al., 2011).

Support for these results was also found when comparisons were made with studies that used objective measures (i.e., accelerometers) to investigate the activity deficit hypothesis. The percentage of time spent in sedentary, moderate, vigorous, and MVPA was significantly correlated with student's movement performance (Wrotniak et al., 2006). Both the time in minutes and percentage of time spent in MVPA was most strongly related to students' performance for object control skills on the *TGMD-2*.

With increased age, children tend to participate in more structured activities such as games or sports that involve equipment. Object control skills may require more experience and knowledge for successful performance than locomotor skills because greater executive functioning is needed. As a result, students that engage in these types of activities have greater opportunities to practice and refine their object control skills and therefore, demonstrate better performance. On the other hand, it appears that greater amounts of time spent in sedentary activities may be detrimental to students' ability to successfully perform various fundamental movement skills. Some engagement in physical activity appears to be better than none at all.

School-based interventions that target movement performance and increase physical activity (or decrease time spent in sedentary activities) among students may be the most effective as children spend the majority of their waking day at school (Hill et al., 2007). There are ample opportunities for students to practice and refine their movement skills and engage in various activities during break times such as recess and in physical education. The skills students develop in school may increase their participation in physical activity outside of school. Programs that incorporate both a physical activity component and a cognitive component (e.g., transfer of knowledge) have been found to positively impact students' movement performance, participation in physical activity, and their knowledge about health issues and the effects of physical activity (Demetriou & Höner, 2012).

4.5.1 Limitations

A few limitations should be considered when interpreting the results of this study. Overall performance on the *TGMD-2* was lower for TD peers than expected given their chronological age, which limited the full range of performance from being examined and may have influenced the strength of the correlations. As well, participation in physical activity is likely to be impacted among students who have not developed increased proficiency for basic movement skills. Typically developing children have become increasingly more sedentary over the last several years (Colley et al., 2011) with substantial increases reported for childhood obesity (Tremblay et al., 2010). These trends may have contributed to the overall performance of fundamental movement skills by the TD group.

Physical activity levels were also only examined among students who adhered to the physical activity monitoring protocols. Initially, data from 24 of 38 students was analyzed based on 4 days (3 weekdays and 1 weekend day) of wear time followed by 35 students who met the monitoring protocol for 2 weekdays only. Adherence to both of the monitoring protocols was greater in my study compared to the Canadian Health Measures Survey. However, further investigation is still required using a larger sample to determine differences in physical activity levels among these groups of students.

The two groups of students included in this research demonstrated difficulties in academics and/or movement, as opposed to having a formal diagnosis of LD or DCD.

However, it is important to examine and identify difficulties demonstrated among students at an early age when intervention is most effective (Missiuna, Rivard, & Bartlett, 2003). Students who demonstrate behaviours associated with a diagnosis of LD or DCD often go unrecognized until they have completed several years of formal schooling because trained professionals are required to rule out other potential factors that may be the result of their difficulties such as varying rates of development (American Psychiatric Association, 2013). As such, knowledge gained from this study is valuable in that it will contribute to the development of teaching strategies and instruction to improve the (learning and) performance of fundamental movement skills among students with AD and MD early on in order to increase their participation in physical activity.

4.5.2 Future Direction

This was the first study that compared physical activity levels among students with AD and MD and examined performance of more functional movement skills that students may use in physical education or play in relation to objective estimates of their physical activity levels. The finding of this study necessitate the need for research to further examine the minimum number of monitoring days required for accurate estimates of physical activity among children. Moreover, the results related to physical activity and the activity deficit hypothesis illustrate the need for intervention in school settings. Interventions that target these various factors will not only afford opportunities for students with MD to achieve the health-related benefits associated with increased physical activity, but TD students as well.

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CHAPTER 5: Summary

In North America, approximately 8% of school-aged children demonstrate specific learning difficulties relative to their academic performance (Centers for Disease Control and Prevention, 2011). Between 50 and 62% of these children who have difficulty learning in the classroom also have difficulty learning and performing movement skills in the gymnasium (Miyahara, 1994; Pieters, Desoete, Roeyers, Vanderswalmen, & Van Waelvelde, 2012; Vuijk, Hartman, Mombarg, Scherder, & Visscher, 2011). However, not all children who demonstrate learning difficulties in various academic areas receive a diagnosis or the appropriate services. Furthermore, (learning) difficulties displayed in physical education are not included as part of the diagnostic criteria for learning disorders (LD). Although approximately 5 to 6% of school-aged children are believed to demonstrate impairment in the motor domain (APA, 2000), relying exclusively on children who already have a formal diagnosis for inclusion in research may underestimate prevalence rates and our understanding of the range of impairments experienced among children who have difficulty performing movement skills.

This thesis is comprised of three manuscripts that collectively examine the range of impairments during the performance of movement skills among students 7 to 10 years of age with academic difficulties (AD) and movement difficulties (MD). Understanding similarities and differences in motor impairment among these students will provide valuable knowledge related to the implications of participation in physical activity. The specific objectives of these manuscripts were: (1) to compare motor and executive functioning abilities among students with AD and MD to determine similarities and differences in levels of impairment underlying the performance of movement; (2) to compare movement performance between students with AD, MD, and their typically developing peers to describe differences in their performance of fundamental movement skills; and (3) to examine physical activity levels for each of the three groups and subsequently, the relationship between movement performance and physical activity.

5.1 Hypotheses

Based on previous literature (Miyahara, 1994), approximately 50% of students with AD were expected to demonstrate MD, with similarities in motor impairment demonstrated among students with AD that also display MD and students with MD. Students with motor impairment were also expected to demonstrate greater levels of impairment in executive functioning. When comparisons were made between students with AD, MD, and typically developing peers on the performance of more functional movement skills, differences were expected to result due to the difficulties demonstrated among students with AD and MD. It was hypothesized that similar impairments would be demonstrated for locomotor and object control skills among students with AD and MD. And last, students with proficient movement skills should demonstrate greater physical activity levels because of their ability to use and practice these skills in various activities. This means typically developing students should have spent the most amount of time in moderate-to-vigorous physical activity (MVPA) compared to students with AD and MD.

5.2 Summary of Findings

The first manuscript provided a brief review on motor abilities and executive functioning among students with LD and developmental coordination disorder (DCD). While research has examined children identified as having LD versus those identified with DCD individually and found similar levels of impairment, underlying processes have not been compared between the two groups directly. Similar impairments were found for students with AD and MD on tasks within the *Movement Assessment Battery for Children* that required manual dexterity and balance, but not ball skills. Students with MD demonstrated immature movement patterns of the hands and throwing arm for aiming and catching tasks and displayed difficulty applying and judging the appropriate amount of force. However, impairment in executive functioning was most evident among students that experienced a range of difficulties for both academic and movement tasks that were 9 and 10 years of age according to the results of the *Barkley Deficits in Executive Functioning Scale*.

In order to obtain a better understanding of the aforementioned impairments, it is important to examine performance of more functional movement skills that students may use in play or physical education. Previous research has primarily focused on the performance of ball catching among children with DCD, with limited research available on the range of impairments experienced among students with LD. The results of the second manuscript revealed that students with MD demonstrated significantly less proficient performance on locomotor (*PE-Metrics*) and object control skills (both *TGMD-2* and *PE-Metrics*) than students with AD and their typically developing peers who were matched on chronological age (± 2 months) and sex. Students with MD tended to demonstrate variable and immature movement patterns and impaired aspects of movement that impact performance, which may be due to the use of inefficient movement strategies. However, when compared to normative data, students with AD and typically developing peers did not demonstrate proficient performance of these fundamental movement skills either.

Difficulties demonstrated in the performance of various movement skills may have the greatest impact on children's participation in physical activity because it restricts their ability to utilize and adapt these skills in age-appropriate activities. As a result, this may place these children at greater risk for secondary health consequences associated with inactivity (Cairney et al., 2010). Only a few studies have quantified physical activity levels of children at risk for DCD, with movement performance assessed using tests of motor abilities. In the third manuscript, students with MD were found to be significantly less active than their same-aged peers, and spent less time in more physically demanding activities associated with moderate and MVPA. It appears that students who engage in higher levels of physical activity tend to demonstrate more proficient movement skills than students who are predominantly inactive, as the time spent in MVPA was most strongly correlated with students' performance for object control skills.

Other factors may impact physical activity participation among children such as a lack of confidence in physical abilities (Hay & Missiuna, 1998; Piek, Dworcan, Barret, & Coleman, 2000), perceptions of physical and sport competence (Cairney, Hay, Faught, Mandigo, & Flouris, 2005), and enjoyment of physical activity and education (Cairney et al., 2007). Although these factors are important to consider, the results of this manuscript underscore the necessity for early intervention among children who demonstrate MD to help them develop the skills necessary to engage in increased physical activity.

5.3 Final Comments

Difficulties in various academic areas such as reading, writing, math, and physical education are often displayed among children during formal years of schooling. However, not all children who demonstrate (learning) difficulties in these academic areas receive a diagnosis or the appropriate services. School-based research is an excellent means to access many of these children since they spend the majority of their waking day at school. For this reason, interventions that aim to improve movement performance and increase physical activity levels among children that demonstrate MD are believed to be the most effective. Unfortunately, school-based research can be very challenging due to time constraints with regard to assessment, limited space available, and involvement of several persons (e.g., principals, teachers) aside from the participants. However, knowledge gained from this type of research has great potential to improve practice in school settings and benefit children of all abilities.

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Appendix A

University of Regina

OFFICE FOR RESEARCH, INNOVATION AND PARTNERSHIP

MEMORANDUM

DATE: October 18, 2012

TO: Chantelle Zimmer
329 Frontenac Drive
Regina, Sk S4S 5T6

FROM: Dr. Larena Hoeber
Chair, Research Ethics Board

Re: **Movement Skill Performance and Physical Activity Levels Among Children with Learning Disabilities or Movement Difficulties (File # 16S1213)**

Please be advised that the University of Regina Research Ethics Board has reviewed your proposal and found it to be:

☑ 1. APPROVED AS SUBMITTED. Only applicants with this designation have ethical approval to proceed with their research as described in their applications. For research lasting more than one year (Section 1F). **ETHICAL APPROVAL MUST BE RENEWED BY SUBMITTING A BRIEF STATUS REPORT EVERY TWELVE MONTHS.** Approval will be revoked unless a satisfactory status report is received. Any substantive changes in methodology or instrumentation must also be approved prior to their implementation.

☐ 2. ACCEPTABLE SUBJECT TO MINOR CHANGES AND PRECAUTIONS (SEE ATTACHED). Changes must be submitted to the REB and approved prior to beginning research. Please submit a supplementary memo addressing the concerns to the Chair of the REB.** Do not submit a new application. Once changes are deemed acceptable, ethical approval will be granted.

☐ 3. ACCEPTABLE SUBJECT TO CHANGES AND PRECAUTIONS (SEE ATTACHED). Changes must be submitted to the REB and approved prior to beginning research. Please submit a supplementary memo addressing the concerns to the Chair of the REB.** Do not submit a new application. Once changes are deemed acceptable, ethical approval will be granted.

☐ 4. UNACCEPTABLE AS SUBMITTED. The proposal requires substantial additions or redesign. Please contact the Chair of the REB for advice on how the project proposal might be revised.

Larena Ho

Dr. Larena Hoeber

cc: Dr. Kerry Staples, KH&S

** supplementary memo should be forwarded to the Chair of the Research Ethics Board at the Office for Research, Innovation and Partnership (Research and Innovation Centre, Room 109) or by e-mail to research.ethics@uregina.ca

Phone: (306) 585-4775
Fax: (306) 585-4893
www.uregina.ca/research

Appendix B

Dear Student and Parent:

As part of my MSc program, we are conducting a study that examines how children with learning difficulties perform basic movement skills needed for participation in various activities. In addition, we are interested in the relationship between children's movement performance and their subsequent physical activity levels. As such, the learning resource teacher has referred your child to us as a potential participant in our study.

Participants will be assessed on varying fundamental movement skills such as running, jumping, catching, and kicking. Assessment will require 30 minutes. Moreover, participants' physical activity levels will be recorded using accelerometers; a small, lightweight device that captures one's movement. Children will be required to wear the accelerometer, attached to an adjustable waist belt, for a week. In order to better understand differences in movement and physical activity levels among children, you will be asked to complete a questionnaire on your child's self-regulation skills. This will require 15 minutes of your time. There are no known or anticipated risks to your child by participating in this research**.**

This study is important because the relationship between movement skill performance and physical activity levels among children with learning difficulties is largely unknown. We are interested in whether children with greater movement skills spend more time in moderate-vigorous physical activity, and their potential to meet Health Canada guidelines (60 minutes per day) for physical activity. Additionally, we want to determine what aspects of movement skills are impacted among children who may learn these skills differently. Participants' performance of fundamental movement skills will be videotaped to ensure accurate scoring of their movement skill ability.

We hope to compare motor skills among children with learning difficulties to those with movement difficulties. Therefore, a standardized motor skills test involving balance, ball activities, and manual dexterity will be administered to your child. This will require about 15 minutes. All parts of the study (except physical activity monitoring) will occur at your child's school and will be conducted by a trained graduate student from the University of Regina.

All data collected, including the videotapes will remain in a secure laboratory at the University of Regina and will be used for research purposes only. Names will not be associated with any of the data and all children will be assigned a code in order to ensure confidentiality. After analysis, the videotapes will remain in the laboratory and only be available to the research team.

Even if you sign the attached form, your child is free to withdraw without question until June 26th or the completion of data collection, depending on which occurs first. This project has been approved on ethical grounds by the UofR Research Ethics Board. Any questions regarding your child's rights as a participant may be addressed to the committee at 585-4775 or research.ethics@uregina.ca.

We ask that both the parent and child sign the attached form to indicate your willingness to participate. If you have any questions, please do not hesitate to contact me at 540-4971 (zimmer5c@uregina.ca) or my supervisor at 585-4370 (kerri.staples@uregina.ca). Thank you for your time and assistance.

Sincerely,

Chantelle Zimmer	Kerri Staples
MSc Candidate	Assistant Professor, PhD

Participant Consent Form

<u>Project Title:</u> Movement Performance and Physical Activity among Children with Learning and/or Movement Difficulties

<u>Researcher:</u> Chantelle Zimmer, Graduate Student, Department of Kinesiology and Health Studies, University of Regina, (306) 540-4971, zimmer5c@uregina.ca

<u>Supervisor</u>: Kerri Staples, Department of Kinesiology and Health Studies, (306) 585-4370, kerri.staples@uregina.ca

Your signature below indicates that you have read and understand the description provided and are aware that your son/daughter can withdraw from the study at any time for any reason. Withdrawal from the study will not affect services they may be receiving at school. Additionally, you are aware the research will be carried out by Chantelle Zimmer and Kerri Staples and is part of a University of Regina study. The confidentiality of your son/daughter will be ensured.

I freely consent and voluntarily agree for my son/daughter to participate in all phases of the research study.

_________________________ _________________________
Parent/Caregiver's Name Parent/Caregiver's Signature

____
Date

Please discuss the procedures to your son/daughter in a level appropriate to their understanding and have them sign their name where requested below.

_________________________ _________________________
Participant's Name Participant's Signature

____
Participant's Date of Birth

Please check below if you consent to the use of video clips of your son or daughter to be used in research presentations. Their identity will not be revealed and only clips that illustrate their movement skills from a posterior or side view will be used.

_____ I consent to the use of video clips to be used for research presentations

Please return this consent form to your child's learning resource teacher. Thank-you!

Appendix C

Dear Student and Parent:

As part of my MSc program, we are conducting a study that examines children's performance of basic movement skills needed for participation in various activities. In addition, we are interested in the relationship between children's movement performance and their subsequent physical activity levels.

Participants will be assessed on varying fundamental movement skills such as running, jumping, catching, and kicking. Assessment will require 30 minutes. Moreover, participants' physical activity levels will be recorded using accelerometers; a small, lightweight device that captures one's movement. Children will be required to wear the accelerometer, attached to an adjustable waist belt, for a week. In order to better understand differences in movement and physical activity levels among children, you will be asked to complete a questionnaire on your child's self-regulation skills. This will require 15 minutes of your time. There are no known or anticipated risks to your child by participating in this research.

This study is important because the relationship between children's movement skill performance and their physical activity levels is largely unknown. We are interested in whether children with greater movement skills spend more time in moderate-vigorous physical activity, and their potential to meet Health Canada guidelines (60 minutes per day) for physical activity. Additionally, we want to determine what aspects of movement skills are impacted among children who perform at all levels. Participants' performance of fundamental movement skills will be videotaped to ensure accurate scoring of their movement skill ability.

We hope to include children with varying movement ability. As such, a standardized motor skills test involving balance, ball activities, and manual dexterity will be administered to some of the children. This will require about 15 minutes. All parts of the study (except physical activity monitoring) will occur at the school and be conducted by a trained graduate student from the University of Regina.

All data collected, including the videotapes will remain in a secure laboratory at the University of Regina and will be used for research purposes only. Names will not be associated with any of the data and all children will be assigned a code in order to ensure confidentiality. After analysis, the videotapes will remain in the laboratory and only be available to the research team.

Even if you sign the attached form, your child is free to withdraw without question until June 26th or the completion of data collection, depending on which occurs first. This project has been approved on ethical grounds by the UofR Research Ethics Board. Any questions regarding your child's rights as a participant may be addressed to the committee at 585-4775 or research.ethics@uregina.ca.

We ask that both the parent and child sign the attached form to indicate your willingness to participate. If you have any questions, please do not hesitate to contact me at 540-4971 (zimmer5c@uregina.ca) or my supervisor at 585-4370 (kerri.staples@uregina.ca). Thank you for your time and assistance.

Sincerely,

Chantelle Zimmer
MSc Candidate

Kerri Staples
Assistant Professor, PhD

Participant Consent Form

Project Title: **Movement Performance and Physical Activity among Children with Learning and/or Movement Difficulties**

Researcher: Chantelle Zimmer, Graduate Student, Department of Kinesiology and Health Studies, University of Regina, (306) 540-4971, zimmer5c@uregina.ca

Supervisor: Kerri Staples, Department of Kinesiology and Health Studies, (306) 585-4370, kerri.staples@uregina.ca

Your signature below indicates that you have read and understand the description provided and are aware that your son/daughter can withdraw from the study at any time for any reason. Withdrawal from the study will not affect services they may be receiving at school. Additionally, you are aware the research will be carried out by Chantelle Zimmer and Kerri Staples and is part of a University of Regina study. The confidentiality of your son/daughter will be ensured.

I freely consent and voluntarily agree for my son/daughter to participate in all phases of the research study.

___________________________ ___________________________
Parent/Caregiver's Name Parent/Caregiver's Signature

____
Date

Please discuss the procedures to your son/daughter in a level appropriate to their understanding and have them sign their name where requested below.

___________________________ ___________________________
Participant's Name Participant's Signature

____
Participant's Date of Birth

Please check below if you consent to the use of video clips of your son or daughter to be used in research presentations. Their identity will not be revealed and only clips that illustrate their movement skills from a posterior or side view will be used.

_____ I consent to the use of video clips to be used for research presentations

Please return this consent form to your child's physical education teacher. Thank-you!

Appendix D

Performance Criteria for Locomotor Skills Adapted from the Test of Gross Motor Development (2nd ed.)

Skill	Performance Criteria
Run	Arms move in opposition to legs, elbows bent
	Brief period where both feet are off the ground
	Narrow foot placement landing on heel or toe (i.e., not flat footed)
	Nonsupport leg bent approximately 90° (i.e., close to buttocks)
Gallop	Arms bent and lifted to waist level at takeoff
	A step forward with the lead foot followed by a step with the trailing foot to a position adjacent to or behind the lead foot
	Brief period when both feet are off the ground
	Maintains a rhythmic pattern for four consecutive gallops
Hop	Nonsupport leg swings forward in a perpendicular fashion to produce force
	Foot of nonsupport leg remains behind body
	Arms flexed and swing forward to produce force
	Takes off and lands three consecutive times on preferred foot
	Takes off and lands three consecutive times on nonpreferred foot
Leap	Take off on one foot and land on the opposite foot
	A period where both feet are off the ground longer than running
	Forward reach with the arm opposite the lead foot
Horizontal jump	Preparatory movement includes flexion of both knees with arms extended behind body
	Arms extend forcefully forward and upward reaching full extension above the head
	Take off and land on both feet simultaneously
	Arms are thrust downward during landing
Slide	Body turned sideways so shoulders are aligned with the line on the floor
	A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot
	A minimum of four continuous step-slide cycles to the right
	A minimum of four continuous step-slide cycles to the left

Appendix E

Performance Criteria for Object Control Skills Adapted from the Test of Gross Motor Development (2nd ed.)

Skill	Performance Criteria
Striking a stationary ball	Dominant hand grips bat above nondominant hand
	Nonpreferred side of body faces the imaginary tosser with feet parallel
	Hip and shoulder rotation during swing
	Transfers body weight to front foot
	Bat contacts ball
Stationary dribble	Contacts ball with one hand at about belt level
	Pushes ball with fingertips (not a slap)
	Ball contacts surface in front of or to the outside of foot on preferred side
	Maintains control of ball for four consecutive bounces without having to move feet to retrieve it
Catch	Preparation phase where hands are in front of the body and elbows are flexed
	Arms extend while reaching for the ball as it arrives
	Ball is caught by hands only
Kick	Rapid continuous approach to the ball
	An elongated stride or leap immediately prior to ball contact
	Nonkicking foot placed even with or slightly in back of the ball
	Kicks ball with instep of preferred foot or toe
Overhand throw	Windup is initiated with downward movement of hand/arm
	Rotates hip and shoulders to a point where the nonthrowing side faces the wall
	Weight is transferred by stepping with the foot opposite the throwing hand
	Follow through beyond ball release diagonally across the body toward the nonpreferred side
Underhand roll	Preferred hand swings down and back, reaching behind the trunk while chest faces cones
	Strides forward with foot opposite the preferred hand towards the cones
	Bends knees to lower body
	Releases ball close to the floor so ball does not bounce more than four inches high

Appendix F

Performance Criteria for Locomotor and Object Control Skills Adapted from the Grade 2 Assessment of the PE-Metrics

Skill	Movement Skill Criteria
Approach and kick a ball	Form, distance, accuracy (measure across 3 trials)
Dribble with hand and jog	Form, space and distance, ball control
Galloping	Form, consistency
Jump forward	Form, distance (measure across 3 trials)
Jumping and landing	Jump onto box, jump off the box
Locomotor sequence	Locomotor pattern, transitions (run, hop, gallop)
Overhand catching	Form, catches the ball (measure across 3 trials)
Skipping	Form, consistency
Striking with paddle	Success, control

Appendix G

University of Regina

Dear Parent/Guardian:

Your child was given an accelerometer today at school in order to measure their physical activity levels over the course of a week. The accelerometer is programmed to begin recording movement at 9:00am on **May 6**. Please use the following guidelines:

- Ensure your child wears the accelerometer around their waist (on the right hip) **each day from morning to night**. If you feel your child will not remember to put on the accelerometer first thing in the morning, it can be worn while sleeping.
- When your child bathes/showers or if they go swimming, the accelerometer will need to be removed for the duration of that activity since the device is water resistant but not waterproof.

Please complete the daily log provided below by recording your child's wakeup time, when the accelerometer was removed/replaced (bathing, swimming, or other reasons), and bedtime. This information will help in determining their amount of physical activity.

Student's Name: ______________________________ Accelerometer ID: _______________

Start time 9:00am

End time midnight

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Wakeup Time							
Bathing							
Swimming							
Other (naptime)							
Bedtime							

Please return the accelerometer and this log sheet to your child's classroom teacher on **May 13.** Thank you again for your assistance in this research project.

Sincerely,

Chantelle Zimmer
zimmer5c@uregina.ca

Dr. Kerri Staples
kerri.staples@uregina.ca