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Article Title: Fundamental Movement Skills in Children With and Without Movement Difficulties

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Abstract

The performance of various fundamental movement skills is important for children with movement difficulties (MD) to be successful in physical education and play. The current study aimed to provide a detailed understanding of the aspects impaired in the performance of static and dynamic locomotor and object control skills among children with MD, identified with the *Movement Assessment Battery for Children*, relative to their same aged peers without MD. Children, 7-10 years, were recruited from three elementary schools. Eighteen children with MD (mean age = 9.14 years, SD = 0.97) and 18 without MD (mean age = 9.12 years, SD = 0.97) participated in the study. Quantitative and qualitative aspects of their movement performance were assessed using the *Test of Gross Motor Development* (*TGMD-2*) and *PE Metrics*. Children with MD demonstrated significantly poorer performance than children without MD for locomotor skills on the *PE Metrics* and object control skills on both the *TGMD-2* and *PE Metrics*. The findings of this study suggest that children with MD primarily demonstrate immature movement patterns, inefficient movement strategies, and impaired aspects of movement that impact their performance for dynamic object control skills.

Keywords: children, developmental coordination disorder, movement performance, physical activity

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Introduction

Physical literacy is a concept that has become widely accepted in physical education, recreation, and sport programs over the past decade (Canadian Sport for Life, 2016; Mandigo, Francis, Lodewyk, & Lopez, 2009), and is intended to capture the essence of what quality physical activity programs aim to achieve (Society of Health and Physical Educators [SHAPE] America, 2014; Tremblay & Lloyd, 2010). The basic tenets of physical literacy is children should learn fundamental movement skills in multiple contexts (e.g., physical education, recreation, sport), multiple environments (e.g., ground, water, air, snow/ice), and from multiple sources (e.g., physical educators, coaches, parents, peers). Fundamental movement skills consist of basic locomotor and object control skills that emerge following the ability to walk, which should be mastered by age 10 (Burton & Miller, 1998). These skills ultimately lay the foundation for more advanced and sport specific skills to develop in late childhood and early adolescence.

Physical literacy not only benefits the development of motor competence in children, but also cognitive and affective development (Physical and Health Education [PHE] Canada, 2015a), which are collectively thought to influence participation in physical activities over the life course (Whitehead, 2010). Conversely, impaired performance of fundamental movement skills in children may negatively impact their participation in physical activity (Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996; Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2010), and decrease opportunities to be physically active. Physical education may offer children the best opportunity to become competent and confident movers given its mandate to provide all children with the knowledge and skills necessary to develop a positive attitude toward physical activity (PHE Canada, 2015b).

Children with developmental coordination disorder (DCD) demonstrate difficulties in the acquisition and execution of fine and/or gross motor skills that, in turn, substantially impacts their ability to perform activities of daily living, academic tasks, leisure activities, and engage in play (American Psychiatric Association [APA], 2013). The onset of DCD symptoms occurs during the developmental period and is not better explained by an intellectual or visual impairment, or attributed to a neurological condition affecting movement (e.g., cerebral palsy, muscular dystrophy, degenerative disorder). In North America, it is estimated that 5 to 6% of school aged children may have the disorder (APA, 2013), yet many of these children do not receive a formal diagnosis or the appropriate services to address their movement difficulties (Wilson, Neil, Kamps, & Babcock, 2013). Children who do not have a definitive diagnosis, and are referred to as having movement difficulties (MD), are often the focus of school-based research given the complexities that exist in the identification and diagnosis of DCD among educational and healthcare professionals (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012). The disorder is characterized as a hidden impairment, meaning these children are generally not identified and diagnosed (if at all) until years after they have begun to experience significant MD and the performance of fundamental movement skills should have been mastered. Understanding how children who demonstrate characteristics associated with DCD perform these skills has important implications for physical education instruction.

Typically developing children usually perform locomotor skills by late childhood with ease and competence in a variety of contexts (Francis, Johnson, Lloyd, Robinson, & Sheehan, 2011). This differs from children with DCD who demonstrate shorter strides, higher cadence (Deconinck et al., 2006; 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) during walking and running. These difficulties are often attributed to a lack of neuromuscular strength (Raynor, 2001) and postural control (Kane & Barden, 2012), and may impact performance of other locomotor skills requiring similar movement patterns. Running, stopping, dodging, and chasing are common locomotor movements performed in childhood games and activities (Francis et al., 2011), but may be difficult for children with DCD to participate in because of their MD. Yet, children with DCD are likely to experience even greater difficulty participating in games and activities that require them to receive, retain, or propel an object such as a ball, due to the increased complexity of the task.

Hence, the majority of current research has focused on the impaired aspects of ball catching among children with DCD because it is an integral part of participation in games and activities. In order to catch a ball successfully, a child must predict where the ball will end up and execute the proper sequence of movements within a continually changing environment (Ricken, Savelsbergh, & Bennett, 2004). The ability to predict the trajectory of the ball is thus a key component to the outcome of a catch. Children with DCD require more viewing time and visual information to predict the ball's final location compared to typically developing peers (Lefebvre & Reid, 1998), which is characteristic of early learners who rely almost exclusively on visual information to guide the execution of their movements. Because of this, children with DCD demonstrate immature and variable movement patterns with respect to their body, arms, and hands for ball catching (Utley & Astill, 2007). For example, these children may place the palms of their hands up as they wait for the ball or attempt to trap the ball against their chest to catch it. These less efficient movement patterns may contribute to a higher number of grasping errors (Van Waelvelde, De Weerdt, De Cock, Smits-Engelsman, & Peersman, 2004).

Children with DCD demonstrate more successful catching performance when the ball is thrown directly to them, since their limbs move an equal distance to arrive at the same end point. Although, some children may step or jump when the ball is thrown directly to their body, even though the task characteristics do not demand such action (Przysucha & Maraj, 2010). Heavy reliance on visual information to predict the speed, weight, size, and direction of the ball may result in inefficient movement strategies, and poorly timed and coordinated movements (van der Meulen et al., 1991). 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). It appears that one side of the body moves in children with DCD and the other side attempts to "catch" up (Astill, 2007). Some children with DCD may initiate their hand movements earlier to compensate for difficulties in timing the catch (Estil, Ingvaldsen, & Whiting, 2002).

The majority of studies to date have described different aspects of performance as being impaired for a limited range of fundamental movement skills (walking, running, ball catching) in children with DCD, but children's games and activities incorporate a variety of these skills with differing complexities. Static skills require the child to maintain a controlled, stationary position or body shape during the performance of that skill, whereas dynamic skills require the child to maintain control of the body as it moves during the performance of the skill (Payne & Isaacs, 2008). Researchers and practitioners may assume or make inferences that difficulties in bilateral coordination demonstrated among children with DCD for walking, for example, would also be present in other locomotor skills with similar movement patterns. Although, whether these impairments affect several or only certain fundamental movement skills among children with DCD, and to what extent, has not been empirically examined. This research aims to provide a more detailed understanding of the aspects impaired in the performance of a greater variety of static and dynamic locomotor and object control skills that are required for the successful participation of children with MD in physical education and play. It was hypothesized that children with MD would demonstrate impaired performance for both locomotor and object control skills when compared to their same aged peers without MD.

Method

Participants

The University Research Ethics Board and the Public School Board granted approval for this study. Forty-two children, between 7 and 10 years, participated and were recruited from three elementary schools of similar socioeconomic status. The primary researcher was involved in physical education classes prior to data collection to help classroom teachers identify children with MD through observation. Particular attention was paid to children who demonstrated difficulty with ball (e.g., catching, throwing) and balance skills, as well as the ability to run smoothly and stop with control. Following the identification of children with MD via observations, informed consent was obtained from parents and all children provided their assent to participate. The *Movement Assessment Battery for Children – 2nd edition* (Henderson, Sugden, & Barnett, 2007) was administered to confirm the inclusion of these children in the study. A total test score ≤ 16th percentile was used as it indicates borderline motor impairment and thus, children at risk for DCD.

Twenty-four children were initially identified as having MD, but results of the *Movement Assessment Battery for Children* indicated that only 20 of those children demonstrated difficulties in the motor domain. Moreover, two children with MD who met the inclusion criteria had extreme scores on the two subsequent movements assessments and were considered outliers. Therefore, the four children who did not demonstrate motor impairment and the two children with extreme scores were not included in the analyses. Children who demonstrated characteristics associated with specific learning disorders (n = 8) or attention deficit hyperactivity disorder (n = 1) were included in this study since these disorders often co-occur with DCD (Dewey, Kaplan, Crawford, & Wilson, 2002). However, children with sensory impairments, intellectual impairments, or other neurodevelopmental disorders such as autism spectrum disorder were not recruited for participation. The primary researcher and principal at each school then identified children without MD based on their sex and chronological age (± 2 months) to facilitate group matching. Based on school records, no children had any indication of atypical development. Parental consent and child assent was subsequently obtained for this group of children. Comparisons were made between 18 children with MD (M_{age} = 9.14 years, SD = 0.97; 12 boys, 6 girls) and 18 without MD (M_{age} = 9.12 years, SD = 0.97; 12 boys, 6 girls).

Measures

Movement performance is a broadly used term that refers to observable, goal-directed movements that can be described in terms of quantity and quality (Burton & Miller, 1998). Quantitative descriptors focus on products or outcomes with regard to the intended movement goal, whereas qualitative descriptors of performance refer to the movement pattern or form used to execute a particular skill (Burton & Miller, 1998). For example, the outcome of the movement provides the researcher with information regarding the efficiency or accuracy of performance, while the components of a skill (or coordination of these movements) provide the greatest insight when trying to determine which aspect of the movement is impaired and where additional instruction should be targeted. It seems plausible that children who demonstrate poor performance have not yet mastered the specific skill criteria required for competence to be achieved. Once this coordination process is mastered, more attention can be placed on the outcome of their performance. In other words, examining both quantitative and qualitative aspects of movement skills may provide greater understanding of where specific difficulties in the performance of these skills occur to better inform instruction. This was achieved in the study through the inclusion of two movement assessments not previously used to examine movement skill performance in children with MD.

Test of gross motor development (2nd ed.). The *Test of Gross Motor Development* (*TGMD-2*; Ulrich, 2000) is a standardized assessment for children 3 to 10 years that focuses on the performance of fundamental movement skills children perform during physical education and play. Administration of the assessment occurs in a familiar setting for children such as a gymnasium or school playground. These factors contribute to the ecological validity of the *TGMD-2*. The assessment consists of two subtests comprised of six movement skills each. The locomotor subtest includes the run, gallop, hop, leap, horizontal jump, and slide and the object control subtest is comprised of striking a stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll. There are 3 to 5 performance criteria for each skill that represent a mature movement pattern of that skill, which is expected to be mastered by age 10 (refer to Appendices A and B). 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 competence. The internal consistency, test–retest, and interrater reliability of the *TGMD-2* vary between .85 and .98 for both subtests. The individual skills representing each subtest have been shown to be valid indicators of locomotor and object control abilities (χ^2 = 280.30; GFI = .96; AGFI = .95).

PE metrics: Assessing national standards 1-6 in elementary school. The *PE Metrics* (SHAPE America, 2010) was primarily designed for use by physical educators to provide a comprehensive assessment of performance in physical education. It is divided into three subtests (Kindergarten, Grade 2, and Grade 5) to target movement skills relevant to each specific age group. The Grade 2 subtest was chosen for this study because it focuses on the performance of 11 fundamental movement skills that should be mastered by age 10 (Burton & Miller, 1998); many of which are also examined in the *TGMD-2* but would be considered more complex or dynamic. Children were assessed on the gallop, jump forward, jumping and landing combination, locomotor sequence, skip, approach and kick a ball, dribble with hand and jog, overhand catch, and striking with paddle. The dance and gymnastics sequences were not assessed because children were not provided time to create and practice their routines beforehand, which is a part of the standardized administration procedures. For the locomotor sequence, all children were instructed to run, hop, and then gallop to maintain a consistent order of performance for all children.

Each fundamental movement skill is assessed based on the performance criteria that make up the mature form of that skill, which are similar to the criteria used in the *TGMD-2*, as well as the outcome(s) of the movement (see Appendix C). Outcome measures for the kick would include the distance and accuracy of the ball that was kicked. The movement form and outcome(s) of each skill are scored from 0 to 4 over one (e.g., gallop) or three trials (e.g., jump forward), depending on the nature of the skill, where a higher score reflects greater competence. Composite scores differ for the individual skills, and range between 6 and 24, as a result of the number of components relevant to each skill. The *PE Metrics* is widely used by physical educators in the United States because it contains appropriate content that reflects the national standards for physical education (Dyson et al., 2011), and provides an objective means of assessment. The scores (0 to 4) associated with the different components of each skill enable physical educators to discriminate between children who demonstrate different levels of competency. The test-retest reliability for the complete Grade 2 subtest is high (.99), with estimates ranging between .59 and .97 for the individual skills (Fox et al., 2011), and the inter-rater reliability (.80) amongst trained raters considered good. The *PE Metrics* has the potential to add valuable information to our understanding of where difficulties in performance occur among children with MD as it emphasizes both the quantitative and qualitative aspects of movement, even though it has not been previously adapted for use in research.

Procedure

During the months of May and June, children were administered both assessments within a two-week period. Administration of the assessments occurred in the school gymnasium for 2 of the 3 elementary schools. Due to a lack of gym availability at the third school, children were assessed outdoors on a tarmac during morning school hours, but not including recess. The assessments were counterbalanced within each group as well as across the entire sample to ensure that the order in which the assessments were administered did not have an effect on the movement performance of the two groups.

The equipment used, preparation for each skill, and instructions provided for the *TGMD-2* adhered to research protocol. A demonstration with verbal instructions was provided for each skill, followed by a practice trial. A second demonstration was given if the child did not understand the task following the practice trial. The *PE Metrics* is used by physical educators to assess children 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*. Children were provided with both verbal instructions and a demonstration for each skill, rather than instructions read verbatim alone.

Each assessment was videotaped for scoring purposes. A trained research assistant who was blind to the group and age of each child was the primary scorer for all assessments. To ensure accuracy of scoring, the primary researcher scored 6 *TGMD-2* and 6 *PE Metrics* assessments for each group of children (for a total of 24 of 72 assessments) to determine the percentage of agreement for the performance criteria of all locomotor and object control skills. Agreements of 96.4 and 97.8% were found for children with and without MD respectively on the *TGMD-2* and 91.0 and 86.7% on the *PE Metrics*. Although consensus between the two raters was high, agreement for the *PE Metrics* was lower than the *TGMD-2* due to the greater range in scoring criteria (0 to 4 versus 0 or 1) for the various components of each skill.

Data Analysis

Preliminary data analyses were conducted to ensure that children with and without MD did not differ in their movement performance on the two assessments as a result of the order in which the assessments were administered. Results of the independent samples t-tests were not statistically significant for the order effect; therefore, it was not controlled for in subsequent analyses. Pearson correlation coefficients were also computed to lend support for the creation of the locomotor and object control subtest for the *PE Metrics*, to parallel the division of locomotor and object control skills in the *TGMD-2*. To test the null hypotheses, analyses of variance (ANOVAs) were used to examine between group differences in the raw subtest scores of the

TGMD-2 and *PE Metrics*. To further examine group differences in the performance of individual fundamental movement skills, the number and percentage of children with and without MD who met all performance criteria for each skill was computed. All statistical analyses were performed with SPSS statistical software, version 21.0 for Windows. The statistical significance was set at .05 for the correlational analyses, with a Bonferroni correction used for the independent samples t-tests and ANOVAs to reduce the likelihood of committing a Type 1 error.

Results

Correlations Between the Locomotor and Object Control Subtests and Skills

Children’s locomotor and object control subtest scores on the *PE Metrics* were significantly and moderately related to the locomotor (r = .530, p = .001) and object control (r = .503, p = .002) subtest scores on the *TGMD-2*, which are empirically reliable and valid. These correlational results also illustrate associations in the performance of individual fundamental movement skills that include similar aspects of performance, but may require different levels of competence. The gallop (r = .391, p = .018), leap (r = .424, p = .010), and jump forward (r = .371, p = .026) were associated with the jumping and landing combination, which necessitates bilateral coordination for different types of jumps (1 foot take off, 2 foot landing; 2 foot take off, 2 foot landing). The jumping and landing combination (r = .338, p = .04) was also correlated with the locomotor sequence, both of which require smooth transitions between the sequence of movements. With respect to the object control skills, the stationary dribble (r = .461, p = .005) was significantly correlated with the dribble with one hand and jog. However, there were not as many significant correlations between the object control skills of the two assessments as expected, which may be attributed to greater emphasis on the outcomes of the movement for the *PE Metrics* skills. For example, children were scored on the distance and accuracy (e.g., ball reaches target line between cones) of their kick on the *PE Metrics*, but not the kick on the *TGMD-2*. If the children sampled have not yet mastered the movement process for the kick, their outcome scores would be poor, decreasing the composite score of that skill.

Performance on the Locomotor and Object Control Subtests and Skills

Four ANOVAs were conducted to examine differences between children with and without MD in the overall performance of locomotor and object control skills on the *TGMD-2* and *PE Metrics*. The results were not statistically significant for the locomotor subtest scores on the *TGMD-2* [$F(1, 34) = 1.69$, $p = .20$], but were significant for the object control subtest scores on this assessment [$F(1, 34) = 3.84$, $p = .05$, partial $\eta^2 = .10$], as well as both the locomotor [$F(1, 34) = 4.33$, $p = .04$, partial $\eta^2 = .11$] and object control [$F(1, 34) = 4.04$, $p = .05$, partial $\eta^2 = .11$] subtest scores on the *PE Metrics*. Refer to Table 1 for the group means, range of raw scores, and standard deviations on the locomotor and object control subtests and skills for the *TGMD-2* and Table 2 for group descriptive statistics on the *PE Metrics*.

The percentage of children with and without MD who mastered all the performance criteria for each fundamental movement skill in the *TGMD-2* and *PE Metrics* are illustrated in Tables 3 and 4. Differences in performance between the two groups can be observed in one of the individual locomotor skills from the *TGMD-2* (leap), *PE Metrics* (locomotor sequence), and two of the individual object control skills from the *TGMD-2* (stationary dribble, catch). There were 4 to 6 fewer children with MD who demonstrated mastery for these skills when compared to their peers without MD. These results are based on the number of performance criteria achieved for each skill relative to the maximum performance criteria that can be attained.

Quantitative and Qualitative Descriptors of Performance

The aspects of performance that were absent or not successfully achieved by children with MD are discussed, and intended to complement and expand on the previous results (see the appendices for complete results). The qualitative descriptors of performance are emphasized since they inform physical education instruction for children with MD the most, although reference is made to quantitative descriptors. Significant differences in performance were not found between the two groups of children on the locomotor subtest of the *TGMD-2*. However, few children with MD mastered all performance criteria for the leap and had difficulties reaching forward with the arm opposite the lead foot. Difficulties coordinating oppositional movements of the arms and legs may have impacted their performance for other locomotor skills such as the hop and slide. Many children with MD did not produce sufficient force by using their arms or swinging their leg in a pendular fashion to propel their body forwards when hopping, and had difficulty keeping their body aligned with the line on the floor while moving sideways. On the locomotor subtest of the *PE Metrics*, children with MD did not execute the proper sequence of movements or demonstrate smooth transitions when performing the locomotor sequence (run, hop, gallop). These difficulties also affected their performance for the jumping and landing combination on this assessment, as children with MD were often unable to transition between a 1 foot take off and 2 foot landing on the box and a 2 foot take off and 2 foot landing off the box.

For the object control skills on the *TGMD-2*, over half of the children with MD did not demonstrate the performance criteria for the stationary dribble. Their inability to maintain control of the ball impacted their performance for the dribble with hand and jog on the *PE Metrics*. Children were unable to jog at a consistent speed and at times, they stopped dribbling because the ball rolled outside of the designated boundaries. Their performance for catching a ball on both assessments was primarily impacted by their inability to make contact with the ball or catch it with only their hands. When the ball was thrown at chest level for the *TGMD-2*, children with MD attempted to catch the ball by trapping it against their body and they often jumped to catch the ball when it was thrown slightly above their head for the *PE Metrics*.

Almost no children with MD mastered the performance criteria for the underhand roll in the *TGMD-2*, and the approach and kick a ball and striking with a paddle from the *PE Metrics* as well; although, their peers without MD demonstrated comparably poor performance. For the underhand roll, children in both groups tended to not take a stride forward with the foot opposite of their preferred hand and did not lower their bodies to release the ball without it bouncing. Their poor performance for the kick on the *PE Metrics* was a result of not contacting the ball with the instep of the foot and following through, which caused the ball to move outside the boundaries and not reach the target line. Furthermore, children struggled with striking with a paddle because they were only able to strike the ball one or two consecutive times (instead of the required five) and moved outside of the 10 foot square several times within a 30 second period.

Discussion

This study moved beyond previous research by examining quantitative and qualitative aspects of several static and dynamic fundamental movement skills, which provided a more detailed understanding of the aspects impaired in the performance of these skills among children with MD. Support was found for our hypothesis that children with MD would demonstrate poorer performance for both locomotor and object control skills, when compared to children without MD. Although specific fundamental movement skills and performance criteria are highlighted in this study, we acknowledge that children with MD are not a homogenous group meaning not all children demonstrated these difficulties (or to the same extent). Given the small sample, the results of this study should be interpreted with caution.

Children in both groups performed comparably on the locomotor subtest of the *TGMD-2*, but significant differences were revealed between children with and without MD on the locomotor subtest of the *PE Metrics*. The gap in performance between the two groups was greater on the *PE Metrics*, meaning children with MD demonstrated greater difficulties in the performance of more complex locomotor skills. The impaired aspects of locomotor skills observed in this study complement the findings in the literature, even though the nature of the movement patterns examined were different based on the measures used. Previous research examined the kinetics and kinematics of walking and running using motion analysis, whereas the current study assessed locomotor performance using two movement assessments with specific performance criteria. Ultimately, children with MD appear to demonstrate difficulties in bilateral coordination (Rosengren et al., 2009), especially for skills that necessitate different movement patterns of the right and left sides of the body, and use inefficient movement patterns (Chia et al., 2013; Deconinck et al., 2006; Deconinck et al., 2010) that result in poor performance.

Impairments in the qualitative aspects of ball catching performance found in this study were also similar to previous findings. Children with MD demonstrated very poor performance for this object control skill because they were unable to catch the ball with only their hands (Utley & Astill, 2007; Van Waelvelde et al., 2004). They often attempted to trap the ball against their body, which is a strategy used by early learners. However, children with MD included in this research also demonstrated poor performance for other object control skills involving the use of a ball (stationary dribble, underhand roll, approach and kick a ball, dribble with hand and jog) and paddle (striking with one hand). Raw scores obtained by children with MD on the object control subtest of the *PE Metrics* were substantially lower and more heterogeneous than the subtest scores on the *TGMD-2,* which indicates these children were less competent in the performance of more dynamic object control skills. Although the effect sizes for performance on the object control subtest of each assessment were similar, the true difference between the two groups may have been masked on the *PE Metrics* due to the greater range in scores. The effect size calculation reflects the difference of means between the two groups, relative to the standard deviation of scores. Because the maximum raw score children can obtain on the object control subtest of the *PE Metrics* (68) is greater than the *TGMD-2* (48), and there was a greater range in scores obtained among children with MD on the object control subtest of the *PE Metrics*, the mean raw scores on the object control subtest of the *PE Metrics* were substantially lower (i.e., the mean difference between children with and without MD was 7.72 on the *PE Metrics* versus 3.56 on the *TGMD-2*). While this study examined performance of object control skills beyond catching, children with MD still demonstrated immature movement patterns for their chronological age (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. The predominant focus on ball catching performance in the literature appears just, but future research should focus on the quantitative and qualitative aspects of performance for other object control skills aside from catching.

Although children with MD demonstrated significant difficulties for a variety of fundamental movement skills, their peers without MD did not demonstrate mastery of the majority of these skills either. The decreasing physical activity levels of children today could be a plausible explanation for the unexpected performance of children without MD. Over the last several years, children have become increasingly more sedentary (Colley et al., 2011). Children in both Canada and the United States recently received a D- for their overall physical activity on the 2014 Report Cards, which assess different behaviors that contribute to children’s physical activity (Active Healthy Kids Canada, 2014; Dentro et al., 2014). However, Canadian children received a C+ and American children a C- for organized sports and physical activity participation. While these grades are satisfactory, it is important to remember that children only learn and practice a limited range of skills in organized programs. It is imperative that children acquire a diverse repertoire of skills that are adaptive to perform fundamental movement skills in different contexts and environments (Davids, Button, & Bennett, 2008). If children are not proficient in these basic skills, they may have limited opportunities to participate in physical activities in adolescence because they will not have the prerequisite skills to engage in more complex activities and sport (Clark & Metcalfe, 2002).

Limitations

Children with MD included in this research demonstrated difficulties in physical education and were subsequently tested on the *Movement Assessment Battery for Children* to determine their level of motor impairment (≤ 16^{th} percentile), whereas their peers without MD were not. This assessment serves as a screening tool for children with MD, rather than a method of confirming the range of performance that would be considered typical in children. The children with MD did not have a formal diagnosis of DCD, which may be viewed as a limitation, but is also the reality of school-based research since not all children who demonstrate difficulties in core academic areas receive a formal diagnosis or the appropriate services to address their difficulties in learning and performance. The sample was comprised of 18 children with MD and 18 without MD. Further investigation using a larger sample (with greater power) is required to determine the range of fundamental movement skills impacted among children with MD and the aspects of performance impaired. Group differences in the performance of individual fundamental movement skills were not statistically analyzed due to limited power. The *TGMD-2* and *PE Metrics* were chosen for this study because they include fundamental movement skills typically performed at school, but assessment of these skills did not occur in the context of physical education or recess. A controlled environment afforded children the opportunity to perform these skills to the best of their ability, but may not provide a valid representation of how these skills are performed in different physical activity contexts.

Conclusion

Fundamental movement skills are not acquired naturally through maturational processes (Haywood & Getchell, 2009), 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 the primary school curriculum and therefore, schools should be the primary context for children to learn and become competent movers. Understanding where children with MD demonstrate difficulties in the performance of a variety of fundamental movement skills allows educators to provide more individualized and targeted instruction for these children with respect to performance criteria that span across different skills. For example, individualized instruction for children with MD should focus on movement patterns of the right and left sides of the body and the generation of appropriate force and momentum.

During primary school years, instruction needs to be focused on children’s ability to understand, communicate, apply, and analyze different movement forms, particularly fundamental movement skills, because they are the building blocks for more complex skills to develop (PHE Canada, 2015a). Children who develop these capacities will be able to perform a variety of fundamental movement skills across a broad range of health-related physical activities, including extracurricular and organized activities (Clark & Metcalfe, 2002). These skills should be taught using a developmentally appropriate framework to afford all children the opportunity to learn and practice at their own pace of skill development (Martin, Rudisill, & Hastie, 2009).

References

Active Healthy Kids Canada (2014). *Archived report cards*. Retrieved from http://www.activehealthykids.ca/

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Astill, S. (2007). Can children with developmental coordination disorder adapt to task constraints when catching two-handed? *Disability and Rehabilitation*, *29*, 57-67. doi: 10.1080/09638280600947856

Blank, R., Smits-Engelsman, B., Polatajko, H., & Wilson, P. (2012). European Academy for Childhood Disability (EACD): Recommendations on the definition, diagnosis and intervention of developmental coordination disorder (long version). *Developmental Medicine and Child Neurology*, *54*, 54-93. doi: 10.1111/j.1469-8749.2011.04171.x

Bouffard, M., Watkinson, E. J., Thompson, L. P., Causgrove Dunn, J. L., & Romanow, S. K. E. (1996). A test of the activity deficit hypothesis with children with movement difficulties. *Adapted Physical Activity Quarterly*, *13*, 61-73.

Burton, A. W., & Miller, D. E. (1998). *Movement skill assessment*. Champaign, IL: Human Kinetics.

Cairney, J., Hay, J., Veldhuizen, S., Missiuna, C., & Faught, B. E. (2010). Developmental coordination disorder, sex and activity deficit over time: A longitudinal analysis of participation trajectories in children with and without coordination difficulties. *Developmental Medicine and Child Neurology*, *52*, 67–72. doi: 10.1111/j.1469-8749.2009.03520.x

Chia, L. C., Licari, M. K., Guelfi, K. J., & Reid, S. L. (2013). A comparison of running kinematics and kinetics in children with and without developmental coordination disorder. *Gait and Posture*, *38*, 264-269.

Clark, J. E., & Metcalfe, J. S. (2002). The mountain of motor development: A metaphor. In J. E. Clark & J. H. Humphrey (Eds.), *Motor development: Research and review*. Reston, VA: National Association for Sport and Physical Education.

Canadian Sport for Life. (2016). *Fundamental skills*. Retrieved from http://canadiansportforlife.ca/physical-literacy.

Colley, R. C., Garriguet, D., Janssen, I., Craig, C. I., Clarke, J., & Tremblay, M. S. (2011). Physical activity of Canadian children and youth: Accelerometer results from the 2007 to 2009 Canadian health measures survey. *Health Reports*, *22*, 15-23.

Davids, K., Button, C., & Bennett, S. (2008). *Dynamics of skill acquisition: A constraints-led approach*. Champaign, IL: Human Kinetics.

Deconinck, F. J. A., De Clercq, D., Savelsbergh, G. J. P., Van Coster, R., Oostra, A., Dewitte, G., & Lenoir, M. (2006). Differences in gait between children with and without developmental coordination disorder. *Motor Control*, *10*, 125-142.

Deconinck, F. J. A., Savelsbergh, G. J. P., De Clercq, D., & Lenoir, M. (2010). Balance problems during obstacle crossing in children with developmental coordination disorder. *Gait and Posture, 32*, 327-331. doi: 10.1016/j.psychsport.2011.11.006

Dentro, K. N., Beals, K., Crouter, S. E., Eisenmann, J. C., McKenzie, T. L., Pate, R. R., …Katzmarzyk, P. T. (2014). Results from the United States' 2014 report card on physical activity for children and youth. *Journal of Physical Activity and Health*, *11*, S105-S112.

Dewey, D., Kaplan, B. J., Crawford, S. G., & Wilson, B. N. (2002). Developmental coordination disorder: Associated problems in attention, learning, and psychosocial adjustment. *Human Movement Science, 21*, 905-918. doi: 10.1016/S0167-9457(02)00163-X

Dyson, B., Placek, J. H., Graber, K. C., Fisette, J. L., Rink, J., Zhu, W., …Franck, M. (2011). Development of PE metrics elementary assessments for national physical education standard 1. *Measurement in Physical Education and Exercise Science, 15*, 100-118. doi: 10.1080/1091367X.2011.568364

Estil, L. B., Ingvaldsen, R. P., & Whiting, H. T. A. (2002). Spatial and temporal constraints on performance in children with movement co-ordination problems. *Experimental Brain Research*, *147*, 153-161. doi: 10.1007/s00221-002-1193-7

Fox, C., Zhu, W., Park, Y., Fisette, J. L., Graber, K. C., Dyson, B., …Franck, M. (2011). Related critical psychometric issues and their resolutions during development of PE metrics. *Management in Physical Education and Exercise Science*, *15*, 138-154. doi: 10.1080/1091367X.2011.568367

Francis, N., Johnson, A., Llyod, M., Robinson, D., & Sheehan, D. (2011). *Fundamental movement skills: An educator's guide to teaching fundamental movement skills*. Ottawa, ON: PHE Canada.

Goodway, J. D., & Branta, C. F. (2003). Influence of a motor skill intervention on fundamental motor skill development of disadvantaged preschool children. *Research Quarterly for Exercise and Sport*, *74*, 36–47. doi: 10.1080/02701367.2003.10609062

Haywood, K.M., & Getchell, N. (2009). *Lifespan motor development* (5th ed.). Champaign, IL: Human Kinetics.

Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2007). *Movement assessment battery for children* (2nd ed.). London: Pearson Assessment.

Kane, K., & Barden, J. (2012). Contributions of trunk muscles to anticipatory postural control in children with and without developmental coordination disorder. *Human Movement Science, 31*, 707-720. doi: 10.1016/j.humov.2011.08.004

Lefebvre, C., & Reid, G. (1998). Prediction in ball catching by children with and without a developmental coordination disorder. *Adapted Physical Activity Quarterly*, *15*, 299-315.

Mandigo, J. L., Francis, N., Lodewyk, K., & Lopez, R. (2009). Physical literacy for educators. *Physical and Health Education Journal*, *75*, 27-30.

Martin, E. H., Rudisill, M. E., & Hastie, P. A. (2009). Motivational climate and fundamental motor skill performance in a naturalistic physical education setting. *Physical Education and Sport Pedagogy, 14*, 227-240.

Missiuna, C., Moll, S., Law, M., King, S., & King, G. (2006). Mysteries and mazes: Parents' experiences of children with developmental coordination disorder. *Canadian Journal of Occupational Therapy, 73,* 7-17. doi: 10.2182/cjot.05.0010

Payne, V. G., & Isaacs, L. D. (2008). *Human motor development: A lifespan approach* (7th ed.). New York, NY: McGraw-Hill.

Physical and Health Education Canada. (2015a). *What is physical literacy*? Retrieved from http://www.phecanada.ca/programs

Physical and Health Education Canada. (2015b). *Quality daily physical education*. Retrieved from http://www.phecanada.ca/programs

Przysucha, E. P., & Maraj, B. K. V. (2010). Movement coordination in ball catching: Comparison between boys with and without developmental coordination disorder. *Research Quarterly for Exercise and Sport*, *81*, 152-161. doi: 10.1080/02701367.2010.10599662

Raynor, A. J. (2001). Strength, power, and coactivation in children with developmental coordination disorder. *Developmental Medicine and Child Neurology*, *43*, 676-684.

Ricken, A. X. C., Savelsbergh, G. J. P., & Bennett, S. J. (2004). Coordinating degrees of freedom during interceptive actions in children. *Experimental Brain Research, 156,* 415-421. doi: 10.1007/s00221-003-1797-6

Robinson, L. E., & Goodway, J. D. (2009). Instructional climates in preschool children who are at-risk. Part I: Object-control skill development. *Research Quarterly for Exercise and Sport*, *80*, 533–542. doi: 10.1080/02701367.2009.10599591

Rosengren, K. S., Deconinck, F. J. A., DiBerardino, L. A., Polk, J. D., Spencer-Smith, J., De Clercq, D., & Lenoir, M. (2009). Differences in gait complexity and variability between children with and without developmental coordination disorder. *Gait and Posture, 29*, 225-229.

Sekaran, S. N., Reid, S. L., Chin, A. W., Ndiaye, S., & Licari, M. K. (2012). Catch! Movement kinematics of two-handed catching in boys with developmental coordination disorder. *Gait and Posture, 36*, 27-32. doi: 10.1016/j.gaitpost.2011.12.010

Society of Health and Physical Educators America. (2010). *PE metrics: Assessing national standards 1-6 in elementary school*. Reston, VA: SHAPE America.

Society of Health and Physical Educators America. (2014). *National standards & grade-level outcomes for K-12 physical education*. Champaign, IL: Human Kinetics.

Tremblay, M., & Lloyd, M. (2010). Physical literacy measurement: The missing piece. *Physical and Health Education Journal*, *76*, 26–30.

Ulrich, D. A. (2000). *Test of gross motor development* (2nd ed.). Austin, TX: Pro-Ed.

Utley, A., & Astill, S. L. (2007). Developmental sequences of two-handed catching: How do children with and without developmental coordination disorder differ? *Physiotherapy Theory and Practice*, *23*, 65-82. doi: 10.1080/09593980701211838

Valentini, N. C., & Rudisill, M. E. (2004). An inclusive mastery climate intervention and the motor skill development of children with and without disabilities. *Adapted Physical Activity Quarterly*, *21*, 330–347.

van der Meulen, J. H. P., Denier van de Gon, J. J., Gielen, C. C. A. M., Gooskens, R. H. J. M., & Willemse, J. (1991). Visuomotor performance of normal and clumsy children II: Arm-tracking with and without visual feedback. *Developmental Medicine and Child Neurology*, *33*, 118-129.

Van Waelvelde, H., De Weerdt, W., De Cock, P., Smits-Engelsman, B. C. M., & Peersman, W. (2004). Ball catching performance in children with developmental coordination disorder. *Adapted Physical Activity Quarterly*, *21*, 348-363.

Whitehead, M. (2010). *Physical literacy throughout the lifecourse*. New York, NY: Routledge.

Wilson, B. N., Neil, K., Kamps, P. H., & Babcock, S. (2013). Awareness and knowledge of developmental co-ordination disorder among physicians, teachers, and parents. *Child: Care, Health and Development*, *39*, 296-300. doi: 10.1111/j.1365-2214.2012.01403.x

Wrotniak, B. H., Epstein, L. H., Dorn, J. M., Jones, K. E., & Kondilis, V. A. (2006). The relationship between motor proficiency and physical activity in children. *Pediatrics*, *118*, 1758-1765. doi: 10.1542/peds.2006-0742

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Table 1: *Raw scores on each skill of the locomotor and object control subtest of the TGMD-2*

	MD (n = 18)		Without MD (n = 18)	
	M (range)	*SD*	*M* (range)	*SD*
Locomotor subtest (48)	33.00 (23-44)	6.67	35.56 (25-46)	5.00
Run (8)	6.94 (4-8)	1.43	6.61 (4-8)	1.38
Gallop (8)	5.67 (2-8)	1.91	6.28 (4-8)	1.32
Hop (10)	5.78 (1-8)	1.83	6.83 (3-10)	1.76
Leap (6)	4.72 (3-6)	1.07	5.33 (2-6)	1.14
Horizontal jump (8)	5.94 (0-8)	2.26	6.61 (3-8)	1.58
Slide (8)	3.94 (0-8)	2.62	3.89 (0-8)	2.03
Object control subtest (48)*	34.83 (22-46)	6.55	38.39 (32-47)	4.03
Striking a stationary ball (10)	7.89 (4-10)	2.14	8.78 (6-10)	1.48
Stationary dribble (8)	4.22 (0-7)	2.44	6.17 (4-8)	1.38
Catch (6)	5.39 (3-6)	0.92	5.89 (4-6)	0.47
Kick (8)	6.72 (4-8)	1.27	6.17 (3-8)	1.54
Overhand throw (8)	5.22 (2-8)	2.24	6.22 (4-8)	1.48
Underhand roll (8)	4.89 (2-7)	1.75	5.17 (2-8)	1.86

Note: The maximum score a child can obtain for each movement skill is noted in parentheses following the skill name
* $p \leq .05$

Table 2: *Raw scores on each skill of the locomotor and object control subtest of the PE Metrics*

	MD (n = 18)		Without MD (n = 18)	
	M (range)	*SD*	*M* (range)	*SD*
Locomotor subtest (56)*	41.00 (24-55)	8.76	46.17 (34-53)	5.85
Galloping (8)	5.33 (0-8)	2.11	6.06 (1-8)	1.66
Jump forward (24)	19.89 (11-24)	5.16	21.50 (15-24)	3.19
Jumping and landing combination (8)	4.67 (1-8)	1.81	5.22 (2-6)	1.22
Locomotor sequence (8)	4.72 (2-8)	1.45	5.83 (4-8)	1.62
Skipping (8)	6.39 (0-8)	2.83	7.56 (5-8)	0.92
Object control subtest (68)*	41.89 (19-66)	13.60	49.61 (35-67)	9.00
Approach and kick a ball (24)	15.56 (6-23)	5.06	16.72 (10-24)	4.39
Dribble with hand and jog (12)	6.11 (0-12)	3.82	8.67 (6-12)	1.97
Overhand catching (24)	16.61 (2-24)	7.01	19.44 (12-24)	4.49
Striking with paddle (8)	3.61 (2-8)	1.75	4.78 (2-8)	2.16

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.

* $p \leq .05$

Table 3: *Number and percentage of children in each group who mastered the skills on the TGMD-2*

	MD (*n* = 18)	Without MD (*n* = 18)
Locomotor subtest		
Run	9, 50%	7, 39%
Gallop	4, 22%	4, 22%
Hop	0, 0%	1, 6%
Leap	7, 39%	12, 67%
Horizontal jump	6, 33%	7, 39%
Slide	1, 6%	3, 17%
Object control subtest		
Striking a stationary ball	6, 33%	8, 44%
Stationary dribble	0, 0%	4, 22%
Catch	11, 61%	17, 94%
Kick	6, 33%	4, 22%
Overhand throw	4, 22%	5, 28%
Underhand roll	0, 0%	1, 6%

Table 4: *Number and percentage of children in each group who mastered the skills on the PE Metrics*

	MD (n = 18)	Without MD (n = 18)
Locomotor subtest		
Galloping	3, 17%	3, 17%
Jump forward	9, 50%	9, 50%
Jumping and landing combination	1, 6%	0, 0%
Locomotor sequence	1, 6%	5, 28%
Skipping	12, 67%	14, 78%
Object control subtest		
Approach and kick a ball	0, 0%	1, 6%
Dribble with hand and jog	2, 11%	3, 17%
Overhand catching	5, 28%	5, 28%
Striking with paddle	1, 6%	2, 11%

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Appendix A

Performance Criteria for Locomotor Skills in the *TGMD-2* (Ulrich, 2000)

Skill	Performance Criteria
Run	1. Arms move in opposition to legs, elbows bent 2. Brief period where both feet are off the ground 3. Narrow foot placement landing on heel or toe (i.e., not flat footed)* 4. Nonsupport leg bent approximately 90° (i.e., close to buttocks)*
Gallop	1. Arms bent and lifted to waist level at takeoff* 2. 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* 3. Brief period when both feet are off the ground 4. Maintains a rhythmic pattern for four consecutive gallops
Hop	1. Nonsupport leg swings forward in a perpendicular fashion to produce force* 2. Foot of nonsupport leg remains behind body* 3. Arms flexed and swing forward to produce force* 4. Takes off and lands three consecutive times on preferred foot 5. Takes off and lands three consecutive times on nonpreferred foot
Leap	1. Take off on one foot and land on the opposite foot 2. A period where both feet are off the ground longer than running 3. Forward reach with the arm opposite the lead foot*
Horizontal jump	1. Preparatory movement includes flexion of both knees with arms extended behind body 2. Arms extend forcefully forward and upward reaching full extension above head* 3. Take off and land on both feet simultaneously 4. Arms are thrust downward during landing*
Slide	1. Body turned sideways so shoulders are aligned with the line on the floor* 2. A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead foot* 3. A minimum of four continuous step-slide cycles to the right 4. A minimum of four continuous step-slide cycles to the left

* Indicates the performance criteria children with MD did not execute correctly or at all

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Appendix B

Performance Criteria for Object Control Skills in the *TMGD-2* (Ulrich, 2000)

Skill	Performance Criteria
Striking a stationary ball	1. Dominant hand grips bat above nondominant hand 2. Nonpreferred side of body faces the imaginary tosser with feet parallel 3. Hip and shoulder rotation during swing* 4. Transfers body weight to front foot* 5. Bat contacts ball
Stationary dribble	1. Contacts ball with one hand at about belt level* 2. Pushes ball with fingertips (not a slap)* 3. Ball contacts surface in front of or to the outside of foot on preferred side* 4. Maintains control of ball for four consecutive bounces without having to move feet to retrieve it*
Catch	1. Preparation phase where hands are in front of the body and elbows are flexed 2. Arms extend while reaching for the ball as it arrives 3. Ball is caught by hands only*
Kick	1. Rapid continuous approach to the ball* 2. An elongated stride or leap immediately prior to ball contact* 3. Nonkicking foot placed even with or slightly in back of the ball 4. Kicks ball with instep of preferred foot or toe*
Overhand throw	1. Windup is initiated with downward movement of hand/arm 2. Rotates hip and shoulders to a point where the nonthrowing side faces the wall* 3. Weight is transferred by stepping with the foot opposite the throwing hand* 4. Follow through beyond ball release diagonally across the body toward the nonpreferred side
Underhand roll	1. Preferred hand swings down and back, reaching behind the trunk while chest faces wall 2. Strides forward with foot opposite the preferred hand towards the cones* 3. Bends knees to lower body* 4. Releases ball close to the floor so ball does not bounce more than four inches high*

* Indicates the performance criteria children with MD did not execute correctly or at all

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Appendix C

Components for the Locomotor and Object Control Skills in the *PE Metrics: Assessing National Standards 1-6 in Elementary School* (SHAPE America, 2010)

Skill	Movement Skill Components
Locomotor skills	
Galloping	Movement form*, consistency
Jump forward	Movement form, distance
Jumping and landing	Jumping onto box form*, jumping off the box form*
Locomotor sequence	Locomotor pattern (run, hop, gallop)*, transitions*
Skipping	Movement form, consistency
Object control skills	
Approach and kick a ball	Movement form*, distance and accuracy*
Dribble with hand and jog	Movement form*, space and distance*, ball control*
Overhand catching	Movement form, catches the ball*
Striking with paddle	Success*, control*

* Indicates when the movement form was not executed correctly by children with MD or the performance criteria were absent, and the outcome measures were not achieved