Mediating Influence of Physical Fitness on the Relationship between Academic Performance and Motor Proficiency

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Abstract

Aims

We explored the potential mediating influence of physical fitness on the relationship between academic performance and motor proficiency in children.

Methods

1864 students (F:926, M:938, age 11.91 (SD:0.34). Academic achievement was derived from an average of standardized tests of reading, writing, and math. The Bruininks-Oseretsky Test of Motor Performance (short-form) determined motor proficiency. Fitness (peak oxygen uptake) was established with the Léger 20-m Shuttle Run Test.

Results

OLS regression identified several significant predictors of academic performance. After controlling for age ($p=0.0135$), gender ($p<0.0001$), and parental education ($p<0.0001$), motor proficiency ($p<0.0001$), was significant. After adding physical fitness ($p=0.0030$) to the model the effect of motor proficiency remained significant however the point estimate was reduced from 0.0034 ($p<0.0001$) to 0.0026 ($p<0.0001$).

Conclusions

These results suggest that physical fitness plays a mediating role on the relationship between academic performance and motor proficiency although both aerobic fitness and motor proficiency have independent roles.

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Chapter 1: Introduction

1.1.0 Preamble

As outlined by the Public Health Agency of Canada (2010), there are several factors which influence the health of any given population. One of the twelve identified determinants of health is education and literacy. According to the Public Health Agency of Canada (2010), individuals with low literacy skills are more likely to be unemployed, to experience poorer health, and to have a shorter life expectancy than individuals with higher levels of literacy. Personal health practices and coping skills are also determinants of health outlined by the Public Health Agency of Canada (2010). Knowing the strong influence that education and personal health practices have to overall health status, it is important to gain a further understanding of how these variables interact with each other.

As highlighted by the latest Physical Activity Guidelines for Canadians, it is recommended that children and youth accumulate at least 60 minutes of moderate- to vigorous- intensity physical activity daily in order to experience health benefits (Canadian Society for Exercise Physiology, 2011). Unfortunately, physical inactivity continues to contribute to trends observed by Shields (2006), who found that from 1978 to 2004 the prevalence of overweight Canadian children (ages 2 to 17 years old) increased from 12% to 18%, with the prevalence of childhood obesity rising from 3% to 8%. In 2004, approximately 1.6 million Canadian boys and girls were either overweight or obese, 70% more than 1978. Physical inactivity has been suggested as a major influence in this increase in obesity (Tremblay & Willms, 2003). Aside from the detrimental effects on individual health, physical inactivity also creates a potentially enormous cost for society. Katzmarzyk and Janssen (2004) estimated that, in Canada, physical inactivity could have contributed approximately $5.3 billion to health care costs during 2001. The health costs to individuals and the economic cost to society, highlight the importance of reversing the trend toward a physically inactive lifestyle.

The health benefits that result from embracing a physically active lifestyle are well documented (Strong et al., 2005). As such, increasing physical activity has been the goal of numerous health promotion campaigns, such as participACTION (Bauman, Cavill, & Brawley, 2009). Promoting physical activity among children is difficult. However one point of entry is the school environment. In Ontario, a 2005 policy change, memorandum 138, states that the Ministry of Education recognizes the health benefits of physical activity for children (Ontario Ministry of

Education, 2005). This policy requires each child in a publicly funded elementary school to receive a minimum of 20 minutes of physical activity daily. This has been challenging as this is seen as time taken away from other academic pursuits. However, increased time in physical activity during the school day has been suggested as having a favourable effect on academic performance (Ahamed, Macdonald, Reed, Naylor, Liu-Ambrose, & McKay, 2007). This argument is controversial as some studies report an inverse relationship between physical activity levels and academic performance (Tremblay, Inman, & Willms, 2000). Other researchers have examined the relationship between physical fitness and academic performance and have found a positive association (Chomitz, Slining, McGowan, Mitchell, Dawson, & Hacker, 2009). Differing methods, measurements, and control of potential confounding variables may be the reason for the discrepant results in previous research. Establishing the true relationship between physical fitness and academic performance is essential if policy makers are to make informed decisions regarding increased physical activity in schools.

It is important to note that although physical activity and physical fitness are two different concepts, it is generally accepted that increased activity is required to increase fitness levels (Blair, Cheng, & Holder, 2001). For this reason, it makes it appropriate to review and consider both physical activity and physical fitness, however the main variable of interest in this analysis will be physical fitness.

There are several hypotheses as to why increased fitness might lead to improvements in academic performance. For example, increased circulation of blood during exercise may stimulate a positive neurological response. Some research suggests that brain-derived neurotrophic factors (BDNF) may play an important role in the relationship between bouts of physical activity and cognitive functioning (Ferris, Williams, & Shen, 2007). Whatever the potential physiologic mechanism; it is necessary to first establish the direction of the relationship, and the intent of the research reported here is to explore that question.

When considering children's physical fitness it is necessary to recognize that children are not all equally capable of pursuing physical activities. Children with poor motor competence have been shown to have a significant activity deficit (Cairney, Hay, Faught, Wade, Corna, & Flouris, 2005). Therefore, understanding the role of physical fitness on academic performance requires an appreciation of the varied motor competencies of children. Not all children find physical activity easy and fun. At an international consensus meeting held in 1994, the term Developmental Coordination Disorder (DCD) was introduced in an attempt to create consistency surrounding the ‘clumsy child’ syndrome (Holsti, Grunau, & Whitfield, 2002). Children with this disorder lack motor competence and prevalence estimates in the school-age population are generally between 5% and 8% (Barnhart, Davenport, Epps, & Nordquist, 2003). A more recent study defining DCD using strict criteria suggested that the actual prevalence may be as low as 1.8% (Lingam, Hunt, Golding, Jongmans, & Emond, 2009). In any case a substantial number of children are affected by motor incompetence.

As outlined in the Diagnostic Statistical Manual (DSM-IV, 1994) there are specific criteria that must be met in order to make a diagnosis of DCD. Criterion B is of particular interest in this analysis as it states that motor deficits must significantly interfere with academic achievement or activities of daily living. Although this analysis will not recognize DCD per se, it will examine the interrelationships that motor competence has with academic performance and physical fitness.

Compared to their peers with normal motor function, children with poor motor proficiency are less likely to participate in physical activities (Cairney et al., 2005). Not only are activity levels impacted, but children with motor impairments also have lower cardiorespiratory fitness than their peers with normal motor function (Silman, Cairney, Hay, Klentrou, & Faught, 2011). The relationship between physical fitness and children with motor impairments has been investigated. At this point, there is limited understanding whether or how much physical fitness influences the relationship between motor proficiency and academic performance. Recognizing that children with motor impairments do not have a cognitive deficit allows an examination of this subgroup.

1.2.0 Objective

The objective of this study is to investigate the relationship between a child’s motor proficiency and academic performance while determining the potential mediating role of physical fitness.

Chapter 2: Review of Literature

2.1.0 Review of Literature

In order to set the stage for a better understanding of the relationships under investigation, the principal measures used for each main variable under consideration will be reviewed, followed by a review of the interrelationships between academic performance, motor proficiency, and physical fitness.

2.2.0 Methods of Measurement

Often the reason for differing results between studies lies in differing outcome measures. With this in mind, prior to conducting an in-depth review of the literature of the relationship between academic performance and motor proficiency, it is important to thoroughly understand some of the main outcome measures available. Measures of academic performance, motor proficiency, and physical fitness will be discussed. Although not a main focus of this investigation, many of the studies reviewed discuss physical activity as it is often difficult to discuss physical fitness without addressing physical activity.

2.2.1 Assessing Academic Performance

The main outcome variable in this analysis is academic performance. Therefore, it is vital to establish a valid means of evaluating academic performance. Two measurement approaches are the use of standardized tests and school grades.

2.2.2 Standardized Testing

There are various benefits of standardized tests for students, teachers, administrators, and policy makers alike. Standardized tests are able to provide a snapshot of a child's performance with respect to a common yardstick in comparison to other children (EQAO, 2005). In Ontario, the Ministry of Education has implemented the Education Quality and Accountability Office's (EQAO) grade 3, 6, and 9 testing to provide standardized province wide assessments. It is difficult to validate large scale tests due to cultural differences within and between countries. However, as highlighted by Wolfe, Childs, and Elgie (2004), the EQAO test has put an intricate process in place during item development to ensure a valid and reliable product. A common criticism of large scale standardized tests is that they are restricted to limited aspects of performance. For example, the EQAO tests focus solely on math, reading, and writing, omitting other important domains of a student's performance. A further criticism of relying solely on a single assessment of academic performance includes the negative impact that anxiety plays on test performance (McDonald, 2001). Regardless of these limitations, large scale standardized tests offer a unique opportunity to compare students to a previously established standard.

2.2.3 School Grades

In general, during elementary school a student must achieve passing grades in order to move onto the subsequent grade. However, there are many concerns with teacher assigned grades. Unfortunately when the elementary school teacher is aware of whose work is being assessed, the outcome is subject to bias (Jae & Cowling, 2009). Findings from Cizek, Fitzgerald, and Rachor (1995) suggest that teachers often have 'highly variable and unpredictable' assessment practices. For example, to determine a student's final grade, some teachers use three grades per marking period while other teachers use almost every mark obtained throughout the course of the unit. It is foreseeable that these varying assessment practices may create discrepancies when assessing grades from children attending various schools. As noted by Randall and Engelhard (2009), when assessing a child's academic achievement, some teachers consider non-achievement variables such as a student's ability, effort, and behaviour. Although this may be important for a teacher's purposes; when a pure measure of academic performance is desired these factors may obscure the outcome under investigation.

2.2.4 Assessing Motor Coordination

It is important to note that there is no gold standard to identifying children with motor impairments (Crawford, Wilson, & Dewey, 2001). Identifying motor impairments requires a thorough evaluation of both a child's fine and gross motor skills. Motor proficiency can be assessed using a variety of assessment tools. Among the most common measures are the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) and the Movement Assessment Battery for Children (M-ABC).

2.2.5 Bruininks-Oseretsky Test of Motor Proficiency

The BOTMP is one of the most common motor movement assessments in North American. The complete battery or long format (BOTMP-LF) consists of 46-items to assess children between 4.5 to 14.5 years old (Crawford, Wilson, & Dewey, 2001). The eight subtests within this battery provide an indication of a child's motor disorder. Four of the subtests evaluate gross motor skills, three measure fine motor skills, and one measures both gross and fine motor skills (Düger, Bumin, Uyanik, Aki, and Kayihan, 1999). These eight tests include running speed and agility, balance, bilateral coordination, strength, upper-limb coordination, response speed, visual-motor control, and upper-limb speed and dexterity (Miller, Polatajko, Missiuna, Mandich, & Macnab, 2001). The BOTMP short form (BOTMP-SF) is comprised of 14 items selected from the complete battery. The BOTMP-SF is desirable for studies with larger numbers of participants as it takes approximately 30 minutes to administer as opposed to roughly two hours for the BOTMP-LF (Hay, Hawes, & Faught, 2004). Furthermore, the BOTMP-SF has been validated against the complete battery with inter-correlations between .90 and .91 for children ages 8 to 14 (Bruininks, 1978). Another desirable aspect of the BOTMP is that it does not require clinical experience to interpret the results. Further, it can be administered by trained research assistants as opposed to professionals such as occupational therapists. Finally, the BOTMP-SF has been suggested as a reasonable alternative to the M-ABC when assessing motor impairment in children (Cairney, Hay, Veldhuizen, Missiuna, & Faught, 2009).

2.2.6 Movement Assessment Battery for Children

As noted earlier, there is no gold standard for assessing motor impairment; however the M-ABC has gained popularity as the assessment tool of choice for clinicians and researchers (Chambers, Sugden, & Sanini, 2005). This battery of assessment tools is designed to evaluate children between the ages of 4 to 12 years (Engel-Yeger, Rosenblum, & Josman, 2010). The M-ABC is composed of three performance domains: manual dexterity (3 items), ball skills (2 items), static balance (1 item) and dynamic balance (2 items). As Van Waelvelde, De Weerdt, De Cock, & Smits-Engelsman (2004) stress, the M-ABC is not designed to distinguish between children with a total score above the 25^{th} percentile. The M-ABC can be considered an assessment of motor impairment rather than motor proficiency. The M-ABC has been found to have acceptable reliability and validity (Henderson & Sugden, 1992). As discussed by Cairney, Hay, Mandigo, Wade, Faught, and Flouris (2007), one important feature of the M-ABC is that it was originally developed to be used by clinicians (e.g., occupational therapists). This is an important aspect to consider when determining which motor movement assessment tool is appropriate to utilize during research.

2.2.7 Assessing Physical Fitness

Physical fitness refers to several different characteristics such as cardiovascular fitness, muscular fitness, and speed/agility (Ortega, Ruiz, Castillo, & Sjöström, 2008). With this knowledge, it is important to identify measures that can appropriately assess the desired attributes. This analysis is primarily interested in a child’s cardiovascular fitness, also referred to as cardiorespiratory fitness or aerobic capacity. Cardiovascular fitness is often based on the body's oxygen uptake (VO_2) during exercise. Maximal oxygen uptake (VO_2 max) is the highest rate at which an individual can consume oxygen during exercise, once this point is achieved oxygen uptake reaches a plateau (Armstrong & Welsman, 2008). Although commonly considered as the gold standard measure of aerobic fitness in adults, VO_2 max is perceived differently for children. Children and adolescents can reach exhaustion prior to achieving their full VO_2 max, therefore peak oxygen uptake (VO_2 peak) is recognized as criterion for aerobic fitness in young people (Armstrong, 1998). To assess one's aerobic fitness a variety of laboratory and field measures have been developed.

2.2.8 Laboratory-Based Assessment of Physical Fitness

Laboratory testing is generally executed using a treadmill or a bicycle ergometer (Vanhees, Lefevre, Philippaerts, Martens, Huygens, Troosters, & Beunen, 2005). These direct measures of VO_2 uptake have been accepted as the reference standard for assessing aerobic power for several decades (Patton, Vogel, & Mello, 1982). Taking the cycle ergometer as an example, one would commence the test at a given intensity and then increase the watts each minute until the participant can no longer maintain a specific pedal rate, generally around 75 revolutions per minute (Patton et al., 1982). Expired air is analyzed by a metabolic cart and heart rate is continuously recorded through a heart rate monitor. VO_2 peak can then be expressed as the volume of oxygen consumed per unit of time relative to body mass ($ml \cdot min^{-1} \cdot kg^{-1}$of body mass).

Although direct measurement of VO_2 peak is considered the gold standard measurement of exercise tolerance (Vanhees et al., 2005), several drawbacks limit the utility of this tool. The main limitation of direct measures of VO_2 peak is the cost, it is expensive both in terms of time and cost of the gas analysis (Grant, Corbett, Amjad, Wilson, & Aitchison, 1995). As highlighted by Patton et al. (1982), these limitations make directly measured VO_2 peak unrealistic for epidemiological studies with larger populations.

2.2.9 Field-Based Assessment of Physical Fitness

Several field tests for fitness testing have been developed to provide an alternative to high priced directly measure VO_2 tests. Such tests include, but are not limited to, the one mile run/walk test, the 20-metre shuttle run multistage test (20-MST), and the 6 minute endurance run (Maharm Rowe, Parker, Mahar, Dawson, & Holt, 1997; Léger & Lambert, 1982; van Mechelen Hlobil, & Kemper, 1986). Originally developed by Léger and Lambert (1982), the 20-MST (or adaptations of this test) is among the most commonly used field tests for estimating cardiorespiratory fitness in children and adolescents (Orgega et al., 2008). There have been numerous studies that have validated the 20-MST as an appropriate predictor of a child's VO_2 uptake (van Mechelen et al., 1986; Léger, Mercier, Gadoury, & Lambert, 1988; Ruiz, Silva, Oliveira, Ribeiro, Oliveira, & Mota, 2009). A main benefit of the 20-MST is that a large group of participants can be assessed simultaneously, making it suitable for population based studies (Léger & Gadoury, 1989).

2.3.0 Distinctions between Physical Fitness and Physical Activity

It is important to understand the differences between physical activity and physical fitness as they are often inappropriately used interchangeably. Although physical activity and physical fitness are highly correlated they are distinctly different. Physical activity can be defined as any bodily movement produced by skeletal muscles resulting in energy expenditure (Caspersen, Powell, & Christenson, 1985). Physical fitness is defined as the capacity to perform physical activity and refers to a range of physiological characteristics such as cardiovascular fitness, muscular fitness, and speed/agility (Ortega, Ruiz, Castillo, & Sjöström, 2008). As Blair et al. (2001) explain, physical fitness is primarily, although not exclusively, determined by physical activity levels over the preceding weeks and months. Often, people engage in exercise, which is a subcategory of physical activity, to either improve or maintain components of one's physical fitness (Armstrong, 1998). It is equally important to recognize the differences and relationships that physical activity and physical fitness have with one another. Knowing this, one must explore research that examines the relation both physical activity and physical fitness have to academic performance and motor proficiency as it will help to gain an overall better understanding of the associations that exist.

2.4.0 Relationship Between Academic Performance, Motor Proficiency, and Physical Fitness

The current state of literature investigating the relationship between academic performance, motor proficiency, and physical fitness will now be examined. By examining the strengths and weaknesses of past literature it will set a precedent for the methodologies to be used in the current research.

2.4.1 Inclusion for studies

In order to come to a fuller understanding of our present knowledge of the relationship between motor proficiency, physical fitness, and academic performance this review of literature includes studies that met certain following inclusion criteria. In an effort to review studies relevant to the objective of this study, studies examining motor proficiency (Appendix A) were limited to the following criteria:

- Sample size ≥15
- Participants ≥ 4 years old
- Studies published in English

Studies examining physical activity or fitness were limited to the following criteria:

- Sample size ≥200
- 4 years old < participants ≤ 18 years old
- Studies published in English

As seen in Appendix B, the application of these criteria leaves 15 studies which examine the relationship between physical activity, physical fitness, and academic performance. It is anticipated that an analysis of these articles will illustrate the controversies in the current literature.

2.4.2 Potential Covariates

When examining the relationship under investigation it is important to account for potentially confounding variables. These variables include socioeconomic status (SES), ethnicity, and gender. It is plausible that these variables may have an independent impact on the outcome variable in this analysis, academic performance.

2.4.3 Effects of Socioeconomic Status on Academic Performance

One variable proposed to have an impact on academic performance is SES. A systematic review of literature by White (1982) examined the results of 101 studies considering the relationship between academic performance and SES. A major finding by White (1982) is that SES has a weak, positive correlation with academic achievement. A more recent study by Caldas and Bankston (1997) illustrates individual family poverty status as having a small, negative effect on a child's academic achievement. Further, findings from Caldas and Bankston (1997) suggest that a family's social status has a positive effect on a child's academic achievement. Sutton and Soderstrom (1999) reported a significantly strong, negative relationship between low income and academic achievement. This notion is reinforced by Toutkoushian and Curtis (2005) who recently concluded that variation in school-level outcome variables can be accounted for in large part by socioeconomic factors. Using teachers' reports on family income Patterson, Kupersmidt, and Vaden (1990) found that among the top predictors of a child's academic performance was income level and ethnicity. A more recent meta-analysis by Sirin (2005) concludes that parents'

SES has a strong impact on a child's academic performance. Sirin (2005) discusses three traditional components used to establish a child's SES: parental income, parental education, and parental occupation. Among the studies reviewed by Sirin (2005), parental education was the most common SES component used to estimate SES. After review it is evident that a child's scholastic achievement is significantly influenced by SES (as measured by several indicators). Therefore, it is necessary to control for the independent impact of SES when examining the relationship between physical activity and academic performance.

2.4.4 Effects of Ethnicity and Gender on Academic Performance

Patterson, Kupersmidt, and Vaden (1990) argued that, in addition to SES, there are often demographic variables with a significant impact on academic achievement, specifically ethnicity and gender. Patterson, Kupersmidt, and Vaden (1990) suggest that black children and males are among the most likely to score low on academic tests. In terms of odd ratios, results from Considine and Zappalà (2002) indicated that, compared to males, females were 1.7 times more likely to achieve an 'outstanding' result on their measure of academic performance. Furthermore, Considine and Zappalà (2002) also found a child's ethnicity to be a significant predictor of academic performance. Pomerantz, Altermatt, and Saxon (2002) examined indicators of academic achievement in four main subjects: language, social studies, science, and math. Results indicate that females outperformed males in each subject under investigation. According to Kenney-Benson, Pomerantz, Ryan, and Patrick (2006), in terms of academic performance it is evident that females routinely outperform males.

2.4.5 Motor Proficiency and Academic Performance

The direct relationship between motor proficiency and academic performance has been somewhat neglected in the literature. As reviewed by Geuze, Jongmans, Schoemaker, and Smits-Engelsman (2001), the relationship between academic performance and motor proficiency is often omitted in studies of motor movement impairments. More specifically, of the 34 studies regarding motor proficiency reviewed by Geuze et al. (2001), very few reported any specific aspect of academic performance or activities of daily living that was affected by the child's motor impairment. Although, the studies which have examined the impact of motor coordination on academic performance are limited, it is important to review the current state of the literature.

Fine motor skills are one area of difficulty for children with motor proficiencies challenges. According to Rosenblum and Livneh-Zirinski (2008), while handwriting, children with low motor competence have deficits in timing, duration, and sequencing of movements. Although not implicitly related to academic performance, this relationship is important to note as children are engaged with fine motor movements (primarily handwriting) for approximately 30% to 60% of the school day (Rosemblum, Weiss, & Parush, 2003). A common belief is that the challenges these children face while handwriting may impact their academic performance.

Stephenson and Chesson (2008) used questionnaires and interviews to probe parents about specific issues pertaining to their motor deficient children. The researchers used parents' perceptions to gain a better understanding of the academic difficulties faced by these children. The most prevalent academic difficulties reported by the parents were writing and spelling, followed by mathematics, reading, and other aspects of learning that need fine motor skills (Stephenson & Chesson, 2008). These results are important however limited by the parent reported nature and a sample size of only 35 families. An earlier study by Düger et al. (1999) examined the relationship between a child's results on the BOTMP and his or her academic performance. Academic performance was assessed using school reports, dichotomized into 'successful' and 'unsuccessful'. Results from Düger et al. (1999) indicate that only two of eight subscales of the BOTMP were significantly related to a child's academic performance. Children listed as academically 'successful' had significantly higher scores for measures of balance and upper-limb speed and dexterity. Although an adequate description of an academic performance marker was not provided, these results provide insight into the possible relationship between a child's motor competence and academic achievement.

Analyzing a cohort of very preterm children, Wocadlo and Rieger (2008) used standardized academic tests to examine the relationship between motor proficiency and academic performance. Although participants were preterm, fairly rigid exclusion criteria eliminated children with additional complications such as cerebral palsy. Using the BOTMP and scores on several standardized tests, results indicate that very preterm children with motor difficulties have poorer literacy and numeracy scores compared to normally coordinated children (Wocadlo & Rieger, 2008). It is important to note the generalizability of these results is limited as each participant was born very preterm which may have underlying impacts on the relationship under investigation.

A more complex study by Cantell, Smyth, and Ahonen (1994) followed-up on 115 children (15 years old) 10 years after the initial screening period. Information pertaining to each child's intelligence quotient, motor proficiency, and school performance was collected. Results indicate that each of the six markers of academic performance (Finnish language and literature, first foreign language, mathematics, physical education, music, and drawing) was significantly related to motor competence. More specifically, on average children with low academic achievement were also motor impaired (Cantell, Smyth, & Ahonen, 1994). However, once intelligence quotient was added to the model a significant relationship remained for only drawing, music, and physical education ($p<0.05$). Interestingly these three subjects each require a certain magnitude of motor coordination in order to be successful. These results suggest that motor proficiency significantly impacts portions of a child's academic performance.

As mentioned previously Dewey et al. (2002) examined a group of children with and without motor movement difficulties. Using standardized academic tests (for reading, writing, and spelling abilities) and several measures of motor skills (e.g., BOTMP, M-ABC, and the Developmental Coordination Disorder Questionnaire), Dewey et al. (2002) identified whether a relationship existed between these variables. Participants were categorized as DCD, suspect DCD, and comparison group. Results for 12 measures of academic performance suggest that the comparison group significantly outperformed both the DCD and suspect DCD group on each measure of academic performance ($p<0.001$). With a total sample size of 174 individuals and only 45 identified as having DCD, it would be interesting to observe whether these results hold true at a population level.

Considering the aforementioned studies, there is reason to believe that a significant relationship between motor competence and academic performance exists. A common limitation to this area of study is the implied causal relationship between academic performance and motor proficiency. Until an experimental investigation is executed this causal relationship will remain inferred (Geuze et al., 2001). Although research is reasonably developed in this area, these studies highlight a gap in the literature and warrant the need for future research to examine the relationship between motor proficiency and academic performance more closely. A study using standardized academic scores and reliable measures of motor proficiency should be executed at the population level.

2.4.6 Physical Activity, Physical Fitness, and Academic Performance

Due to its close connection to the main relationship under investigation, it is important to explore the relationship between physical activity and academic performance. Several studies suggest a positive relationship between academic performance and physical activity (Kantomaa, Tammelin, Demakakos, Ebeling, & Taanila, 2010; Sigfúsdóttir, Kristjánsson, & Allegrante, 2007). Some studies suggest that females are the sole beneficiaries of elevated physical activity levels for academic performance (Carlson, Fulton, Lee, Maynard, Brown, Kohl, & William, 2008; Kwak, Kremers, Bergman, Ruiz, Rizzo, & Sjöström, 2009). Other research has demonstrated a positive relationship between physical fitness and academic performance (Chomitz, Slining, McGowan, Mitchell, Dawson, & Hacker, 2009; Castelli, Hillman, Buck, & Erwin, 2007). Relatively few studies have explored the relationship between physical activity and academic performance using high quality experimental study designs. Results from the quasi-experimental studies that have been conducted suggest that, at best, the increased time allocated to physical activity during school hours does not negatively impact a child's academic performance (Sallis, McKenzie, Kolody, Lewis, Marshall, & Rosengard, 1999; Ahamed, MacDonald, Reed, Naylor, Liu-Ambrose, & McKay, 2007; Donnelly, Greene, Gibson, Smith, Washburn, Sullivan, DuBose, Mayo, Schmelzle, Ryan, Jacobsen, & Williams, 2009). There are some studies that have shown no correlation (Daley & Ryan, 2000), or even an inverse relationship (Tremblay, Inman, & Willms, 2000). In order to gain a better understanding of the literature in this field it is important to carefully analyze the state of current evidence. This will help to identify potential reasons for these inconsistencies, as well as identify gaps in our understanding.

Several studies will be discussed in this review of literature, however certain studies such as, but not limited to, Field, Diego, and Sanders (2001), have been omitted due to weak study designs and or poor measures. Sigfúsdóttir et al. (2006) used a cross-sectional approach to examine the relationship between physical activity and academic performance in a representative sample of Icelandic ninth and tenth grade students. Their results suggest that physical activity is a weak but significant ($p<0.05$) predictor of academic achievement after controlling for variables such as gender, parental education, and family structure. A major limitation of this analysis is a dependence on self-reported information for measures of academic performance and physical activity levels. A large degree of bias may be present as children may provide socially desirable results for these variables. Nonetheless, it remains important to note the associations observed by Sigfúsdóttir et al. (2006).

A study by Kwak et al. (2009) addressed some of the limitations of prior research by including objective measures for the core variables under investigation. Using accelerometers as a measure of physical activity and school grades in 17 subjects as measures of academic performance, researchers were able to gather better quality data than some previous studies. Furthermore, Kwak et al. (2009) incorporated cardiovascular fitness into their regression model. Results differed by gender, as vigorous physical activity was significantly associated with academic achievement for females only. These results also suggested a threshold level of physical activity is required to produce benefits for academic performance. On the other hand, only fitness had a significant association with academic achievement for males. These gender differences are interesting and should be examined in future research.

The concept of a threshold effect was also suggested by Coe et al. (2006) who, over the course of one academic school year, examined the effects of physical education class enrolment and overall physical activity on academic performance. There were 214 sixth grade students in the study. Results suggest that timing of physical education enrolment (either 1st or 2nd semester) had no significant impact on school grades or standardized test scores. Although, similar to Kwak et al. (2009), participants who reported performing vigorous physical activity had significantly higher academic scores than their less active counterparts. This reintroduces the concept of a threshold that must be surpassed in order to have a positive impact on academic performance. Results from Coe et al. (2006) are promising however a noteworthy limitation is the lack of control for SES, which has been shown to significantly influence academic performance (Patterson, Kupersmidt, & Vaden, 1990). Furthermore, the generalizability of this article is limited as participants were recruited from only one school in the region, and the participation rate was a mere 36.8% (229 of 622 possible grade six students). Despite these limitations the results provide some important insight into the relationship between physical activity and academic performance.

The threshold effect may explain why only some researchers have found a significant relationship between physical activity and academic performance. As Blair et al. (2001) explain, physical fitness is determined in large part by recent physical activity levels. Arguably, an individual can be physically active without being physically fit; therefore perhaps there is an optimal amount of physical activity required to benefit academic performance. Several researchers have used the Fitnessgram (Castelli et al., 2007; Cottrell, Northrup, & Wittberg, 2007) or a version of it (Chomitz et al., 2009) to examine the relationship between academic performance and physical fitness. These studies support the notion that physically fit children are more likely to outperform their peers on indicators of academic performance, even after controlling for confounders such as SES. These results lend support to the idea proposed by both Coe et al. (2006) and Kwak et al. (2009) who suggest that a threshold of physical activity needs to be achieved in order to have a beneficial impact on one's academic success. This offers an interesting component to the relationship which should not be neglected in future research.

Hoping to monitor trends over time, a longitudinal study by Carlson et al. (2008) observed 5,316 students from kindergarten to grade five. Researchers examined the association between teacher-reported physical education time and academic achievement (mathematics and reading tests expressed as an item response theory scale score). Carlson et al. (2008) accounted for SES in their analysis unlike some previous studies (Coe et al., 2006). Both cross-sectional and longitudinal results were examined in this study. The cross-sectional associations suggest that females in all grades in the low physical education category also had the lowest item response theory scores for mathematics and reading, however this was only significant for kindergarten and first grade. For females in the fifth grade there was a significant difference for reading scores only. There were no significant differences for males in any grade under investigation, again suggesting a gender difference in this relationship.

The longitudinal associations (kindergarten to fifth grade) examined by Carlson et al. (2008) also demonstrated intriguing results. For males there was no association between time spent in physical education class and academic performance. After controlling for grade-level gains, baseline scores, kindergarten program, and selected demographic variables, the item response theory scale score for reading for females in the high physical education versus the low physical education category had a small but significant benefit. For mathematics, females in the high physical education also experienced small but significant benefits compared to individuals in the low categories, even after controlling for selected demographic variables. One major drawback to this analysis was the measure of physical education. Firstly, it is reliant on the teacher's assessment of the child's time spent in physical education which is subject to socially desirable reporting, and may not be a reliable representation of the actual time spent in physical education class. Furthermore, this measure does not give any indication into how physically active a child was during physical education class, it merely assumes that time spent in physical education class is time spent being physically active. Regardless of these limitations the results from Carlson et al. (2008) offer new insight into the relationship under investigation as quality longitudinal studies in this area are rare.

Only a few studies have taken an experimental (vs. observational) approach to examining the association between physical activity and academic performance. Sallis et al. (1999) evaluated the Sports, Play, and Active Recreation for Kids (SPARK) program in South Carolina. Seven elementary schools were randomly assigned into one of three conditions: specialist, trained teacher, and control group. Each of the 759 students was assessed during the fall and spring of fourth, fifth, and sixth grades. Using the Metropolitan Achievement Tests (MAT6 and MAT7), scores for reading, math, and language were acquired. Overall results suggest that the SPARK program, which was designed to improve health-related fitness, had favourable effects on students' academic performance. Over the two year study period, students in the specialist and trained teacher condition spent 76 hours and 57 hours, respectively, less in the classroom compared to the control group. Despite this, there was little evidence that either intervention condition had a damaging effect on a child's academic achievement.

Unfortunately, over the duration of this study the MAT6 test of academic performance changed to a new version, MAT7. Although the new version was similar, it forced the researchers to analyze the sample as two separate cohorts, ultimately decreasing the statistical power of the associations found. Finally, researchers did not discuss controlling for physical activity outside of schools hours, therefore the opportunity for co-intervention was present. Regardless of these limitations, the strong study design allows the results from Sallis et al. (1999) to offer important insight into the influence a physical fitness program can have on a child's academic achievement.

Similar to Sallis et al. (1999) a study by Ahamed et al. (2007) implemented the Action Schools! British Columbia (AS! BC) intervention in attempt to increase physical activity among fourth and fifth grade students in local elementary schools. Schools were randomly assigned to one of three conditions; liaison schools, champion schools, and usual practice schools. Essentially the liaison schools were provided activity supplies and aid from an AS! BC facilitator (2-4 hours/week). Champion schools were designated the services of an AS! BC facilitator (1 hour/week) as well as they appointed a facilitator from within the school. Both liaison schools and champion schools were different only in their access to external facilitation, therefore they were combined to create the intervention group. Usual practice schools did not receive any additional training. In total there were six intervention schools and two usual practice schools. Ahamed et al. (2007) improved on the report by Sallis et al. (1999) by using the Physical Activity Questionnaire for Children (PAQ-C) to measure leisure time activity levels. Academic performance was assessed using the Canadian Achievement Test (CAT-3) which evaluates mathematics, reading, and language.

Results from Ahamed et al. (2007) demonstrated that, at baseline, the usual practices schools had significantly higher academic performance scores than intervention schools. Despite the intervention schools partaking in an additional 50 minutes of physical activity per week, over the course of 16 months there was no significant difference in academic performance scores between usual practice and intervention schools. Although students' academic performance was not enhanced from the physical activity it did not deter the students from succeeding academically. Several limitations were evident in the study by Ahamed et al. (2007). First, the proportion of Asians in this area of British Columbia was relatively high in both the usual practice schools (77%) and the intervention schools (55%). This causes issues when trying to generalize the results to a broader population as there may be lifestyles differences between ethnicities. The self-reported nature of physical activity may be prone to bias, however the test-retest reliability of the PAQ-C was fairly adequate at $r=0.75$ and $r=0.82$ for males and females respectively. This study provided some fairly concrete evidence supporting the notion that increased physical activity times during school hours is not harmful to a child's academic achievement.

Similar to the two aforementioned studies, a study by Donnelly et al. (2009) also used an experimental design to examine how physical activity impacts academic performance. Although assessing this association was a secondary aim of their study, proper methodology was used to acquire valid results. A cluster randomized, controlled trial was used to examine 1,527 participants (1,490 remaining at follow up) from 24 schools. The Physical Activity Across the Curriculum (PAAC) intervention was administered to 14 schools for the duration of three years. PAAC was used to promote 90 minutes per week of physically active class lessons. The Wechsler Individual Achievement Test-2nd Edition (WIAT-II-A) was used to assess each child's reading, writing, mathematics, and oral language skills. Results indicated that compared to the control schools, students receiving three years of exposure to the PAAC intervention demonstrated significant improvements in their academic performance (Donnelly et al., 2009). The three year prospective design of this study adds to the strength of the findings. Unfortunately, because this association was only a secondary aim of the study, the details surrounding how results were established are vague. For example, it is unclear which variables were controlled when they examined the impact of the PAAC on academic performance. The longitudinal nature of the study and strength of their measures add important insight into the relationship under investigation.

As discussed earlier, Kwak et al. (2009) was interested in the relationship that both physical activity and fitness have with academic performance. Castelli et al. (2007) was focused on the relationship between physical fitness and academic performance among third- and fifth- grade students. Using the Fitnessgram, which is a battery of fitness tests, results suggest that only the 20 metre shuttle run test, a cardiovascular fitness measure, was a significant predictor of academic performance. The same held true when general academic achievement was separated into reading and math as the outcome variable (Castelli et al., 2007). Although the measure of

SES was limited, in that it relied on whether the child participated in the free/reduced meal program at the school, this study still supports the notion that physical fitness is a significant predictor of academic performance. Of importance to take away from Castelli et al. (2007) is the independent consideration of academic areas as well as the combined scores.

Results from Castelli et al. (2007) were supported by Chomitz et al. (2009). However, Chomitz et al. (2009) used an alternative method to construct a physical fitness variable. Children were tested in five domains based partially on the Fitnessgram used by Castelli et al. (2007), these domains include: cardiovascular fitness, abdominal strength, flexibility, upper body strength, and agility. Logistic Regression revealed students' odds of passing academic tests in math and English increased by the successive number of fitness tests passed. A significant limitation to this research is that fitness data was based on curricular information rather than data collected for research purposes, therefore the reliability is unknown. Furthermore, similar to Castelli et al. (2007), Chomitz et al. (2009) relied on eligibility for a school lunch program as their measure of SES. Nevertheless, these results contribute to the evidence suggesting a positive relationship between academic performance and physical fitness.

Regardless of the numerous studies that suggest a beneficial effect of physical activity and physical fitness on a child's academic performance, there remain some inconsistencies in results. Daley and Ryan (2000) examined the physical activity levels and academic performance of 232 Catholic school students between 13 to 16 years of age. Results suggest that there was no significant association between physical activity and academic performance. It is important to point out several limitations of this research. First, involving participants from one Catholic school, typically known to be in good standing, could offer insight into their findings. Being known as a 'good' school suggests that this school is potentially in a higher socioeconomic location which could ultimately skew results to conclude no significant relationship as perhaps there is a ceiling effect to this relationship. Moreover, lack of control for potentially confounding variables was an issue in this analysis. Finally, generalizability is limited due to the specific population under investigation. With these limitations considered it provides insight into potential reasons why Daley and Ryan (2000) did not observe any significant results.

A study by Tremblay et al. (2000) also had interesting results after looking at the relationship between physical activity and academic achievement. Researchers used four self-reported questions as a marker of physical activity levels, as well as students' mathematics and reading scores as a marker of academic performance. After accounting for SES, gender, number of parents, number of siblings, and self-esteem, Tremblay et al. (2000) concluded that physical activity was inversely related to academic achievement. Although this study included a large sample of 5,146 grade six students, there is one evident limitation. The reliability (0.68) of the four question physical activity measure used by Tremblay et al. (2000) is questionable. Regardless of this limitation, controlling for numerous confounders adds to the validity of the study and offers interesting findings regarding the relationship between physical activity and academic performance.

Although inconsistencies remain, the general consensus appears to be that both physical activity and fitness have a positive relationship with academic performance. Through examining the current literature several important results and factors should be noted and considered in future research. Based on this review the following variables should be included and controlled for in future investigations: gender, age, ethnicity, SES, and self-esteem. Furthermore, quality longitudinal analyses in this area are lacking. In general each of the studies reviewed has a significant limitation that should be addressed when moving forward. Although studies may be strong in one aspect, they tend to be weak in another. It is important to develop a comprehensive study that has both a valid study design as well as strong measures for physical activity and physical fitness, academic performance, and potentially confounding variables. By accounting for these limitations, future analyses will strengthen research in this area. The following section will discuss motor proficiency, another variable known to potentially impact both physical fitness and academic performance, which has been neglected by researchers in this area.

2.4.7 Motor Proficiency and Physical Fitness

Children with motor impairments often experience difficulties in many aspects of their lives. As mentioned previously, children with severe motor impairments typically have problems with gross motor movements such as running (Barnhart et al., 2003). Additionally, fine motor impairment is common, for example handwriting may be problematic for a child with motor impairments (Rosenblum & Livneh-Zirinski, 2008; Miller, Missiuna, Macnab, Malloy-Miller, & Polatajko, 2001). Poor handwriting may lead to a child falling behind academically. Finally, children with motor difficulties are prone to develop psychosocial problems and may be found to have fewer friends compared to the average child their age (Dewey, Kaplan, Crawford, & Wilson, 2002). Each of these impairments could lead to detrimental effects on a child’s well-being and negatively impact the child’s life. It is important to gain a full understanding of the effects of motor deficiencies because, as Cousins and Smyth (2003) demonstrated, these difficulties can be retained moving into adulthood. Furthermore, if children with motor impairments are not addressed appropriately they may be at an elevated risk for coronary vascular disease (Faught, Hay, Cairney, & Flouris, 2005). The relationship between motor competence and a child's physical fitness levels is of particular interest in this analysis and will be discussed below.

With support for the notion that physical fitness has a positive relationship with a child's academic performance, it is important to consider the relationship between motor proficiency and physical fitness. According to Cairney et al. (2005) children with motor movement difficulties are less likely to participate in both organized and free play activities compared to their peers without motor competence problems. Similarly, Wrotniak, Epstein, Jones, and Valerie (2006) suggest that children (ages 8 to 10 years) with low motor competence are significantly less physically active compared to their high motor competent peers. Additionally, Bouffard, Watkinson, Thompson, Causgrove Dunn, and Romanow (1996) discovered that children with movement difficulties were less vigorously active than their age- and gender-matched controls. Moreover, Faught et al. (2005) found that children with low motor proficiency are significantly associated with having poor cardiorespiratory fitness as measured by the Léger 20-m Shuttle Run Test. Wu et al. (2010) and Silman et al. (2011) both found that children with motor impairments have lower VO_2 peak than their children without impairments as measured by laboratory assessments. Other research consistently shows that, compared to their peers with normal motor function, children with motor impairments have inferior cardiorespiratory fitness as well as other domains such as muscle strength, speed or agility, and flexibility (Cantell, Crawford, & Doyle-Baker, 2008; Haga, 2009; Hands, 2008; Schott, Alof, Hultsch, & Meermann, 2007). Although motor incompetency may account for a large part of the reduced physical fitness levels, several researchers have offered potential psychological barrier to engaging in physical activity.

Although not the primary focus of this paper, it is important to note potential explanations for the decreased physical fitness levels among children with low motor coordination. Self-efficacy can be defined as the expectancy of success based on the belief of one's overall performance competence (Wood & Locke, 1987). Children with low motor proficiency perceive themselves as less adequate in their ability to carry out physical activities, and are less competent in basic physical skills (Cairney et al., 2005). These findings suggest that children with low motor competence have lower generalized self-efficacy, resulting in lower physical activity levels (Cairney et al., 2005). Additionally, Skinner and Piek (2001) found that perceived athletic competence was lower in children and adolescents with low motor proficiency compared to their normally coordinated peers. For these reasons Bouffard et al. (1996) propose that children with low motor competence may circumvent physical activity altogether as a coping strategy. This offers a plausible explanation for the reason why children with motor impairments have lower fitness than their counterparts. Although self-efficacy may play an important role in the relationship between physical fitness, academic performance, and motor proficiency, it will not be a primary focus in the current analysis.

Ultimately, a combination of these factors results in children with motor movement difficulties experiencing less joy from physical education class compared to their better coordinated counterparts (Cairney et al., 2007). Using both objective (Wrotniak et al., 2006) and subjective measures of physical activity, the consensus appears to be that children with low motor proficiency engage in physical activity less often than their high motor competent peers (Cairney et al., 2005). Furthermore, as previously noted, children with motor impairments are less physically fit than their motor competent counterparts (Faught et al., 2005). Based on motor proficiency and physical fitness appearing to have a strong relationship, this warrants investigating the mediating role that physical fitness may play on the relationship between motor proficiency and academic performance.

2.5.0 Conclusion

As demonstrated by the studies presented, many factors such as SES, gender, motor proficiency, and physical fitness levels appear to have an impact on a child's academic performance. At this point there is little knowledge regarding the interrelationship between motor coordination, physical fitness, and academic performance. As discussed above, motor proficiency is a significant predictor of a child's academic performance (Dewey et al., 2002), motor proficiency is also significantly associated to a child's physical fitness (Faught et al., 2005), finally physical fitness has also been demonstrated as a significant predictor of academic performance (Castelli et al., 2007). By neglecting the potential mediating role that physical fitness may have on the relationship between motor proficiency and academic performance, a complete and thorough understanding of this relationship may be overlooked. Furthermore, additional research at a population level is needed to gain a more complete understanding of the relationship between motor proficiency, physical fitness, and academic performance. With the current trends in activity levels seen in North America and the increased emphasis being placed on academics, it is essential to invest in gaining a more thorough understanding of the relationship among academic performance, physical fitness, and motor proficiency.

Chapter 3: Methods

3.1.0 Research Design

This study will examine cross-sectional data from a larger, longitudinal study. The Physical Health Activity Study Team (PHAST), funded by the Canadian Institutes of Health Research (CIHR), began following a cohort of Grade 4 students in 2004. The study was conducted in the Niagara region of Ontario, Canada. The PHAST study was given clearance by the Research Ethics Boards of both Brock University and the District School Board of Niagara (Appendix C).

All elementary schools in the District School Board of Niagara were eligible to participate in the study and 75 of 92 schools participated with informed parental consent obtained for 2278 of 2395 (95%) children. This study will examine data from Wave Three (2006) of the PHAST study, when students were in Grade 6. Wave Three was chosen as students were completely familiar with study protocols and results from the provincial EQAO tests were available. Furthermore, it was not until wave three that scores on the BOTMP-SF were available for students from all 75 participating elementary schools.

3.2.0 Study Participants

A total of 2141 students (1062 females, 1079 males) participated in Wave Three of the PHAST study. After cleaning (view Appendix D), complete data from 1864 participants (87.06%) was available for analysis. A series of tests were run to examine whether differences existed between the participants with complete academic data (included in study), compared to those with incomplete academic data (excluded from study). Of main concern was whether those who completed the EQAO tests scored significantly different than their peers for other key variables under analysis (i.e. motor proficiency, fitness, etc.). As seen in Tables 1 - 3, children who have complete EQAO data generally outperform individuals with incomplete academic data in terms of BOTMP percentile and other academic tests. Children who failed to complete one component of the EQAO testing typically did not complete other aspects, this explains the drastic difference between academic scores for those with complete versus incomplete data.

Table 1 - Sample Characteristics of Participants With and Without EQAO Math Data

	Mean (n)	
Characteristic	**Incomplete EQAO Math**	**Complete EQAO Math**
Age (yrs.)	12.04 (111)	11.91* (2025)
VO_2 peak	44.58 (74)	44.98 (1938)
BOTMP (percentile)	55.27 (88)	67.82* (1944)
EQAO Writing	0.49 (62)	3.14** (2025)
EQAO Reading	0.49 (62)	3.13** (2025)

* p<0.05
** p<0.0001

Table 2 - Sample Characteristics of Participants With and Without EQAO Reading Data

	Mean (n)	
Characteristic	**Incomplete EQAO Reading**	**Complete EQAO Reading**
Age (yrs.)	12.05 (102)	11.91* (2034)
VO_2 peak	44.90 (65)	44.97 (1947)
BOTMP (percentile)	58.05 (79)	67.65* (1953)
EQAO Writing	0.10 (53)	3.14** (2034)
EQAO Math	0.18 (53)	3.09** (2034)

* p<0.05
** p<0.0001

Table 3 - Sample Characteristics of Participants With and Without EQAO Writing Data

	Mean (n)	
Characteristic	**Incomplete EQAO Writing**	**Complete EQAO Writing**
Age (yrs.)	12.06 (103)	11.91* (2033)
VO_2 peak	44.86 (66)	44.97 (1946)
BOTMP (percentile)	58.31 (80)	67.64* (1952)
EQAO Math	0.18 (54)	3.09** (2033)
EQAO Reading	0.15 (54)	3.13** (2033)

* p<0.05
** p<0.0001

3.3.0 Measurement of Outcome Variable

The outcome variable in this study is academic performance as measured by performance on the Grade 6 EQAO standardized test. The EQAO test is valid and reliable and has been used at the provincial level since 1996. Although there are no mandated consequences based on a student's results on the EQAO, the test is seen as high-stakes by teachers, parents, and students alike. With this in mind, a relatively high level of motivation by the students is anticipated when completing the test.

Tests are scored by teams of certified Ontario teachers who pass a qualifier test to become an EQAO scorer. Scorers do not score entire booklets; rather they are assigned certain segments to help ensure consistency throughout the marking process. Certain booklets, labelled as validity papers, are pre-scored by scoring leaders. These booklets are then circulated blindly during the scoring period to monitor for both validity and reliability of each scorer (EQAO, 2011).

The test provides separate measures for reading, writing, and mathematics. For each test, a student's raw scores are converted to a scale score. As highlighted in Table 4, subjects are scored on a four point scale which is aligned with the Ontario Curriculum expectations. An average EQAO score was calculated from the total scores on the three separate components to the EQAO test (reading, writing, and mathematics). Analyses will be executed for each subject area independently as well as for an overall academic performance score. This will provide a complete understanding of the relationship under investigation.

Table 4 – EQAO Score Breakdown

Achievement Level	Definition
Level 4	Achievement exceeds the provincial standard
Level 3	Achievement meets the provincial standard
Level 2	Achievement approaches the provincial standard
Level 1	Achievement falls much below the provincial standard

3.4.0 Measurement of Predictor Variables

3.4.1 Motor Proficiency

The BOTMP-SF will be used to determine motor proficiency. The test was administered to three randomly selected blocks of 25 schools over the first three waves of PHAST until each of the participating 75 schools had been tested. The first 25 schools were screened in Spring 2004, the second group of 25 was screened in Spring 2005, and the final group of 25 in Fall 2006. All research assistants attended a two hour training session to learn the proper procedures and protocols when administering the BOTMP-SF. The trainers leading these sessions remained the same during each of the three years that testing took place. Within the schools, the assessment was performed on a one-on-one basis with each child for whom parents had given informed consent. Additional effort was put forth to ensure assessment stations were set up in a fashion that participants would not be influenced by bystanders. Forms were scored by research assistants, not including two fine motor tasks which were scored by a single experienced investigator, with 5% of these randomly selected for scoring by a second experienced assessor.

Past research on motor coordination has used varying cut-offs, typically ranging from the 5^{th}-15^{th} percentile, to establish probable DCD cases (Cairney et al., 2009). However, rather than determining what is the most appropriate cut-off point on the BOTMP-SF, BOTMP-SF scores in rank-percentiles will be treated as a continuous variable during analysis. It is important to note that this analysis does not compare DCD to non-DCD children, rather it examines one criterion that is associated with a diagnosis, of DCD, motor proficiency, on a continuous scale. Therefore, the relationship of motor proficiency with physical fitness and academic performance will be investigated.

3.4.2 Physical Fitness

Physical fitness is also included as a predictor variable. The Léger 20-m Shuttle Run Test (Léger & Lambert, 1982; Léger et al., 1984) is often used to estimate children's maximal oxygen uptake (VO_2 max). As mentioned previously, maximal oxygen uptake is most appropriately considered as VO_2 peak when analyzing children. The test requires participants to run back and forth over a 20 metre span while keeping pace with a pre-recorded sound signal (Léger & Gadoury, 1989). Participants are expected to continue until exhaustion, at which point the last stage completed is used to estimate aerobic capacity. The maximal speed (km h^{-1}) attained during the last stage is used to calculate maximal oxygen uptake. For children, aerobic capacity can be estimated using the following equation: VO_2 uptake ($ml \cdot min^{-1} \cdot kg^{-1}$) = 31.025 + 3.238 (maximal speed, determined by stage completed) – 3.248 (age, years) + 0.1536 (speed x age) (Léger, Mercier, Gadoury, & Lambert, 1988). Peak VO_2 uptake will be used as an indicator of cardiorespiratory fitness and will be considered an independent variable in this analysis.

3.4.3 Measurement of Confounding Variables

There are several variables that may confound the relationship between the predictor variables and the outcome variable. As suggested earlier these variables include ethnicity, SES, gender, and age. The measures used for these variables in this analysis are discussed below.

As discussed in a previous section of this paper, ethnicity has been found to be a significant predictor of academic performance (Patterson, Kupersmidt, & Vaden, 1990). Unfortunately the PHAST study was not permitted to gather data pertaining to a participant's ethnicity. Therefore, a limitation to this research is the lack of control for ethnicity when investigating the relationship between academic performance and physical activity. However the DSBN has a marked homogeneity among its students with the large majority being Caucasian. According to Statistics Canada (2006), the total population of the Niagara region was 421,750. Niagara's population was composed of 26,405 (6.26%) visible minorities and 395,345 (93.74%) were not visible minorities (Statistics Canada, 2006). It is important to note that in comparison to Ontario's ethnic composition, Niagara appears to differ significantly. In 2006, Ontario's total population was 12,028,895 which was composed of 2,745,200 (22.82%) visible minorities and 9,283,695 (77.18%) people who were not visible minorities (Statistics Canada, 2006). This difference is important to consider when generalizing the conclusions of this study beyond the sample under study.

Another potentially confounding variable is the child's SES. As suggested by Toutkoushian and Curtis (2005) certain factors that help determine SES, for example parent education, are associated with student outcomes such as academic performance. This is further supported by Davis-Kean (2005) who concluded that parental education indirectly influences a child's academic achievement. In a review of the relationship between SES and academic achievement, Sirin (2005) found that parental education was the most common SES component used as an indicator of a child's SES. With this in mind, a proxy measure for SES, parental education, was collected through a questionnaire administered to the parent of each participant in Wave One. The parent or primary guardian was asked the highest level of education that they had attained. Eight possible responses were provided: less than high school, high school (or GED), some college, trade certificate college, college, undergraduate degree (BA, BSc), professional degree (MD, LLB, BEng, MBA), and graduate degree (MA, PhD). Although this is not a direct measure of income, it provides a suitable indicator of a child's SES. It is important to include SES in the analysis, as past research has found a significant association with academic performance (Patterson, Kupersmidt, and Vaden, 1990).

3.5.0 Statistical Analyses

All statistical analysis was completed using Statistical Analysis Software (SAS) 9.2. Descriptive statistics were run by gender for all of the continuous variables under investigation: EQAO average, reading, writing, math, physical fitness, motor proficiency percentile, and age (see Table 5). Two Spearman correlation matrixes were developed to help better understand the existing relationships as well as to examine for multicollinearity (view Tables 6-7). A hierarchical multiple linear regression analysis was used to identify whether motor proficiency and physical fitness were independent predictors of academic performance after controlling for age, gender, and parent education. Similarly, logistic regression was used to predict the probability of participants achieving above or below the provincial standard on the EQAO by accounting for motor proficiency and physical fitness after controlling for age, gender, and parent education. Finally, because there is a natural clustering of children within schools, the assumption of independent observations is violated. Due to these clusters, children in one school are apt to score similarly to their peers in the same school. Therefore, hierarchical linear modelling was used to account for the random effect a student's school may have had on the relationship under investigation.

3.6.0 Delimitations

Three factors that merit mention are body mass index (BMI), physical activity, and academic competence. Although each variable may have close ties with the current relationship under investigation, they will not be included in this analysis. An explanation for this decision is as follows. The beneficial impact physical activity can have on a child's BMI is well documented (Doak et al., 2006). However, in terms of the relationship between academic performance and BMI, Datar et al. (2004) suggest that overweight status can be considered a marker, rather than a causal factor, affecting a child's academic performance. With this knowledge, although data is available, BMI will be omitted from the analysis.

Perhaps a more important consideration is the exclusion of specific physical activity measures from this analysis. As suggested by Blair et al. (2001) physical activity and fitness are strongly related. Although not the sole contributor, one must be physically active in order to be physically fit. At a population level measuring physical activity is most practical using surveys often prone to subjective individual responses. Furthermore, surveys leave room for error when estimating intensity, duration, and frequency of activity, which are all important in the assessment of physical activity (Armstrong, 1998). With the opportunity to eliminate this bias it was decided to use objective measures of physical fitness rather than subjective measures of physical activity.

Finally, a variable that will not be considered in this investigation is perceived academic competence. As highlighted by Harter (1982), children have the ability to differentiate between different psychometric properties such as cognitive competence, social competence, physical competence, general self-worth. Harter (1985) included two more properties, social acceptance and behavioural concept, which were included in the Self-Perception Profile for Children. Although these are potentially important aspects, it is beyond the scope of this paper to examine the potential psychometric constructs contributing to a child's academic performance.

Chapter 4: Results

4.1.0 Results

As mentioned previously, the original sample consisted of 2141 grade six students (F = 912, M = 929) from 75 of 92 possible schools in the DSBN. After cleaning for missing and extreme values complete data was available for 1864 subjects (Appendix D). The mean age of the sample at time of testing was 11.90 years. View Table 5 for further descriptive information. Males and females had a significant difference ($p<0.0001$) between their VO_2 peak, BOTMP percentiles, writing, reading, and average EQAO scores.

Table 5 – Sample Characteristics by Gender

	Mean (SD)	
Characteristic	**Female (n=926)**	**Male (n=938)**
Age (yrs.)	11.90 (0.32)	11.92 (0.35)
VO_2 peak ($ml \cdot min^{-1} \cdot kg^{-1}$)	43.92 (4.52)	46.09 (5.72)**
BOTMP (percentile)	63.18 (30.20)	71.93 (28.87)**
EQAO Math	3.08 (0.63)	3.13 (0.67)
EQAO Writing	3.29 (0.53)	3.01 (0.51)**
EQAO Reading	3.21 (0.63)	3.05 (0.64)**
EQAO Average	3.19 (0.52)	3.06 (0.52)**

**** T-test reveals p<0.0001 between genders**

Descriptive statistics examined the distribution and characterization of all variables on interest in numerical format. The assumption of normal distribution was not met for the variables under analysis and data transformations did not improve the normality of the data. With this assumption violated it is important to interpret results with caution.

With the observed differences between genders for certain variables under investigation, a Spearman's correlation matrix is presented for both genders in Table 6 and Table 7. Age appears to have a stronger relationship for males compared to females for the variables under analysis. The only relationships where differences in direction exist is between age and other variables, however these relationships are not significant. All significant relationships are relatively equal in strength and in the same direction. Furthermore, this correlation matrix allowed for a check of whether multicollinearity would potentially present problems. No issues of collinearity were present. With this enhanced understanding of the existing relationships, gender was controlled for in the regression models rather than examining males and females separately.

Table 6 – Spearman Correlation - Females

	Age	VO_2 peak	BOTMP	EQAO Average	Math	Reading	Writing
Age	**1.000**	-	-	-	-	-	-
VO_2 peak	-0.0982*	**1.000**	-	-	-	-	-
BOTMP	-0.0109	0.4434**	**1.000**	-	-	-	-
EQAO Average	0.0502	0.2397**	0.2102**	**1.000**	-	-	-
Math	0.0177	0.2190**	0.1990**	0.8821**	**1.000**	-	-
Reading	0.0475	0.2065**	0.1679**	0.8872**	0.6743**	**1.000**	-
Writing	0.0606	0.2094**	0.2003**	0.8469**	0.6079**	0.6747**	**1.000**

***p <0.05**
****p<0.0001**

Table 7 – Spearman Correlation - Males

	Age	VO_2 peak	BOTMP	EQAO Average	Math	Reading	Writing
Age	**1.000**	-	-	-	-	-	-
VO_2 peak	-0.0880*	**1.000**	-	-	-	-	-
BOTMP	-0.0464	0.4817**	**1.000**	-	-	-	-
EQAO Average	-0.0474	0.2083**	0.2923**	**1.000**	-	-	-
Math	-0.0357	0.2202**	0.2920**	0.8715**	**1.000**	-	-
Reading	-0.0362	0.1304**	0.2295**	0.8661**	0.6151**	**1.000**	-
Writing	-0.0695	0.1881**	0.2527**	0.8354**	0.6006**	0.6370**	**1.000**

***p <0.05**
****p<0.0001**

As seen in Table 8, during the 2006 school year the Niagara region had a comparable number of students at or above the provincial standard (levels 3 and 4) on each of the three EQAO assessment components. This suggests the results from this study may be generalizable to other regions in Ontario with comparable results.

Table 8 – Comparing Niagara to Ontario Grade 6 EQAO Scores

EQAO Assessment Component	Percentage at Levels 3 and 4	
	Ontario (2006)	**Niagara region (2006)**
Grade 6 reading	64%	65%
Grade 6 writing	61%	61%
Grade 6 mathematics	61%	58%

(EQAO, 2006)

4.2.0 Multiple Linear Regression

An attempt to explore the objective of this study was executed by developing several hierarchical linear regression models (Table 9-16). Independent analyses were done to explore the various components of academic performance (reading, writing, and math) as well as an overall academic performance score (EQAO average). All variables were left as continuous except for parental education and gender which are categorical.

As mentioned previously, SES is an important confounder to account for when examining academic performance. Unfortunately data for parental education was available for only 1179/1864 participants in this study. Therefore, multiple linear regression analyses were run without accounting for SES to examine the relationship between academic performance, motor proficiency, and physical fitness using the full sample. At the same time, a parallel analysis examined the relationship between academic performance, motor proficiency, and physical fitness while accounting for the effect of SES, with the limitation that the sample size was decreased approximately 36%.

Table 9 shows the multivariate analysis for EQAO average. In Model 2, the dependant variable was regressed on motor proficiency score while controlling for age and gender. There is a significant effect of motor proficiency on overall academic performance. As a child's motor proficiency increases so too does their overall academic performance (b=0.0043, s.e.=0.0004, p<0.0001). With the addition of physical fitness in Model 3, the coefficient for motor proficiency remains significantly related to overall academic performance however is reduced by 25.6% from Model 2 (b=0.0032, s.e.=0.0004, p<0.0001).

Table 9 – OLS Regression of EQAO Average on Age, Gender, Motor Proficiency, and Physical Fitness

	Model 1	**Model 2**	**Model 3**
Age	-0.0813*	-0.0605	-0.0489
Gender (F=0)	0.1315**	0.1698**	0.1927**
Motor Proficiency	-	0.0043**	0.0032**
VO_2 peak	-	-	0.0152**
Constant	4.0303**	3.4701**	2.7154**
R^2	0.0187	0.0778	0.0956
N	1864	1864	1864

*p<0.05
**p<0.0001

Table 10 shows a parallel analysis, with the inclusion of SES in the model. After accounting for age, gender, and parental education, Model 2 suggests that motor proficiency (b=0.0034, s.e.=0.0005, p<0.0001) remains a significant predictor of academic performance. After physical fitness (b=0.0113, s.e.=0.0030, p<0.0002) is introduced in Model 3, motor proficiency (b=0.0026, s.e.=0.0005, p<0.0001) remains a significant predictor of overall EQAO average, however its effect is reduced by 23.5%. A test for interactions was conducted (i.e. gender*motor proficiency, gender*fitness, fitness*motor proficiency), however there were no significant interactions for the main variables under investigation once all variables were included in the model. Of importance to note is the mediating influence of physical fitness from Table 9 and Table 10 remain stable after accounting for SES in the models.

Table 10 – OLS Regression of EQAO Average on Age, Gender, SES, Motor Proficiency, and Physical Fitness

	Model 1	**Model 2**	**Model 3**
Age	-0.0501	-0.0343	-0.0242
Gender (F=0)	0.1495**	0.1921**	0.2121**
Parental Education	0.0891**	0.0812**	0.0775**
Motor Proficiency	-	0.0034**	0.0026**
Physical Fitness	-	-	0.0113*
Constant	3.3315**	2.9233**	2.3547**
R^2	0.1129	0.1464	0.1566
N	1179	1179	1179

*p<0.05
**p<0.0001

Table 11 examines EQAO reading score as the outcome measure. In Model 2, reading score was regressed on motor proficiency score while controlling for age and gender. Similar to the previous analysis, there is a significant effect of motor proficiency on reading scores such that as a child's motor proficiency increases so does their reading scores (b=0.0041, s.e.=0.0005, p<0.0001). With the addition of physical fitness (Model 3) into the model, motor proficiency remains a significant predictor however its effect is reduced by 26.8% (b=0.0030, s.e.=0.0005, p<0.0001).

Table 11 – OLS Regression of Reading on Age, Gender, Motor Proficiency, and Physical Fitness

	Model 1	**Model 2**	**Model 3**
Age	-0.0840	-0.0645	-0.0539
Gender (F=0)	0.1615**	0.1974**	0.2184**
Motor Proficiency	-	0.0041**	0.0030**
Physical Fitness	-	-	0.0139**
Constant	4.0517**	3.5268**	2.8349**
R^2	0.0183	0.0536	0.0638
N	1864	1864	1864

*p<0.05
**p<0.0001

Table 12 also examines EQAO reading scores with the addition of SES as a confounder variable, note the change in sample size from the previous analysis in Table 11. After accounting for confounding variables in Model 2, motor proficiency (b=0.0026, s.e.=0.0006, p<0.0001) is a significant predictor of EQAO reading score. Once physical fitness (b=0.0109, s.e.=0.0038, p<0.0038) is introduced in Model 3, motor proficiency (b=0.0018, s.e.=0.0007, p<0.0084) remains a significant predictor of EQAO reading score, however its effect is reduced by approximately 30%. A test for interactions was conducted (i.e. gender*motor proficiency, gender*fitness, fitness*motor proficiency), however there were no significant interactions for the main variables under investigation once all variables were included in the model. Once again, when accounting for the potential confounders in this analysis (i.e. age, gender, and SES), the mediating influence of physical fitness remain similar from Table 11 to Table 12.

Table 12 – OLS Regression of Reading on Age, Gender, SES, Motor Proficiency, and Physical Fitness

	Model 1	**Model 2**	**Model 3**
Age	-0.0711	-0.0590	-0.0493
Gender (F=0)	0.1775**	0.2099**	0.2292**
Parental Education	0.0819**	0.0759**	0.0723**
Motor Proficiency	-	0.0026**	0.0018*
Physical Fitness	-	-	0.0109*
Constant	3.5974**	3.2864**	2.7364**
R^2	0.0744	0.0876	0.0941
N	1179	1179	1179

*p<0.05
**p<0.0001

Table 13 shows the regression of EQAO writing score on various predictor variables. In Model 2, writing score was regressed on motor proficiency score while controlling for age and gender. Motor proficiency was again a significant predictor of academic performance when other variables in the model are held constant (b=0.0039, s.e.=0.0004, p<0.0001). Once physical fitness (Model 3) was added into the model motor proficiency remains a significant predictor however its effect is reduced by 25.6% (b=0.0029, s.e.=0.0004, p<0.0001).

Table 13 – OLS Regression of Writing on Age, Gender, Motor Proficiency, and Physical Fitness

	Model 1	**Model 2**	**Model 3**
Age	-0.0704*	-0.0517	-0.0419
Gender (F=0)	0.2843**	0.3186**	0.3380**
Motor Proficiency	-	0.0039**	0.0029**
Physical Fitness	-	-	0.0129**
Constant	3.8465**	3.3439**	2.7055**
R^2	0.0719	0.1171	0.1292
N	1864	1864	1864

*p<0.05
**p<0.0001

Table 14 included the proxy measure of SES, parental education, in the models. After adjusting for age, gender, and parental education, Model 2 suggests that motor proficiency (b=0.0034, s.e.=0.0005, p<0.0001) is a significant predictor of EQAO writing score. With the addition of physical fitness (b=0.0108, s.e.=0.0031, p<0.0004) in Model 3, the effect of motor proficiency (b=0.0026, s.e.=0.0006, p<0.0001) on EQAO writing score drops by 23.5%. No significant interactions were found when all confounding variables were included in the model (i.e. gender*motor proficiency, gender*fitness, fitness*motor proficiency). After accounting for SES as a potential confounder, the mediating influence of physical fitness remains relatively unchanged from Table 13 to Table 14.

Table 14 – OLS Regression of Writing on Age, Gender, SES, Motor Proficiency, and Physical Fitness

	Model 1	**Model 2**	**Model 3**
Age	-0.0214	-0.0055	0.0041
Gender (F=0)	0.3280**	0.3710**	0.3902**
Parental Education	0.0753**	0.0673**	0.0637**
Motor Proficiency	-	0.0034**	0.0026**
Physical Fitness	-	-	0.0108**
Constant	2.9677**	2.5560**	2.0102**
R^2	0.1517	0.1828	0.1914
N	1179	1179	1179

*p<0.05
**p<0.0001

Table 15 shows the regression of EQAO math score on motor proficiency while controlling for various confounding variables. In Model 2, math score was regressed on motor proficiency score while controlling for age and gender. Motor proficiency demonstrated its ability to significantly predict academic performance (b=0.0051, s.e.=0.0005, p<0.0001). After the influence of physical fitness (Model 3) is accounted for, motor proficiency remains a significant predictor of math score however its effect is reduced by 29.4% (b=0.0036, s.e.=0.0005, p<0.0001).

Table 15 – OLS Regression of Math on Age, Gender, Motor Proficiency, and Physical Fitness

	Model 1	**Model 2**	**Model 3**
Age	-0.0895*	-0.0652	-0.0509
Gender (F=0)	-0.0512	-0.0065	0.0218
Motor Proficiency	-	0.0051**	0.0036**
Physical Fitness	-	-	0.0188**
Constant	4.1927**	3.5394**	2.6059**
R^2	0.0036	0.0566	0.0746
N	1864	1864	1864

*p<0.05
**p<0.0001

Finally, Table 16 examines EQAO math score as the dependent variable while accounting for age, gender, and parental education. Model 2 suggests that motor proficiency (b=0.0041, s.e.=0.0006, p<0.0001) is a significant predictor of EQAO math scores when accounting for the confounders of interest. With the addition of physical fitness (b=0.0121, s.e.=0.0037, p<0.0012) into Model 3, motor proficiency (b=0.0033, s.e.=0.0007, p<0.0001) remains significant a significant however its effect is reduced by 19.5%. A test for interactions was conducted (i.e. gender*motor proficiency, gender*fitness, fitness*motor proficiency), however there were no significant interactions for the main variables under investigation once all variables were included in the model. The mediating influence of physical fitness appears to decrease in effect after accounting for SES in Table 16 as compared to Table 15.

Table 16 – OLS Regression of Math on Age, Gender, SES, Motor Proficiency, and Physical Fitness

	Model 1	**Model 2**	**Model 3**
Age	-0.0577	-0.0383	-0.0275
Gender (F=0)	-0.0570	-0.0046	0.0168
Parental Education	0.1102**	0.1004**	0.0965**
Motor Proficiency	-	0.0041**	0.0033**
Physical Fitness	-	-	0.0121*
Constant	3.4294**	2.9275**	2.3175**
R^2	0.0939	0.1274	0.1352
N	1179	1179	1179

*p<0.05
**p<0.0001

4.3.0 Logistic Regression

Further analysis using logistic regression allowed the probability of an event occurring to be estimated at a significance level of p=0.05. The event of interest in this investigation is the occurrence of a child achieving at or above the provincial standard on the EQAO tests (level 3 and level 4) compared to below the provincial standard (level 1 and level 2). This cut-off was used as it aligns with the framework provided in the annual results reports released by the EQAO (EQAO, 2006). Furthermore, a BOTMP cut-point at or below the 10th percentile was chosen as an estimate for children with motor impairments. Children at or below the 10th percentile are commonly considered to have significant motor difficulties (Cairney et al., 2007)

As seen in Table 17, females are 1.71 (CI=1.408-2.086) times more likely to achieve at or above the provincial standard for overall EQAO score, when compared to males. Furthermore, children with higher levels of motor proficiency (>10th percentile) were 2.176 (CI=1.477-3.204) times more likely to achieve at or above the provincial standard on overall EQAO score, when compared to children with motor difficulties. Finally, compared to the lowest fitness quartile, children in the third (OR=1.965, CI=1.134-1.965) and fourth (OR=2.240, CI=1.675-2.995) fitness quartiles are more likely to achieve at or above the provincial standard on overall EQAO score.

Table 17 – Logistic Regression of Overall Academic Performance (above/below provincial standards) on Age, Gender, Motor Proficiency, and Physical Fitness

	Point Estimate (Odds Ratio)	**95% Wald Confidence Limits**	
Age	0.834	0.627	1.109
Gender F vs. M	1.714	1.408	2.086*
Motor Proficiency (High vs. Low)	2.176	1.477	3.204*
Physical Fitness (ref group 1st Quartile)			
2nd Quartile	1.136	0.867	1.488
3rd Quartile	1.493	1.134	1.965*
4th Quartile	2.240	1.675	2.995*
N=1864			

*CI Includes does not include 1

As seen in Table 18, after the accounting for parental education similar results prevailed. Results also suggest that children with parents who have a college diploma (OR=2.103, CI=1.511-2.926), undergraduate degree (OR=3.064, CI=1.965-4.778), professional degree (OR=5.932, CI=2.563-13.729), or graduate degree (OR=4.727, CI=1.571-14.228) are significantly more likely to achieve better academically, when compared to children with parents who have a high school education. After controlling for SES, children with higher motor proficiency and physical fitness continued to have better odds of achieving at or above the provincial standard academically.

Table 18 – Logistic Regression of Overall Academic Performance (above/below provincial standards) on Age, Gender, Motor Proficiency, Physical Fitness, and Parental Education

	Point Estimate (Odds Ratio)	95% Wald Confidence Limits	
Age	0.812	0.557	1.185
Gender F vs. M	1.815	1.395	2.362*
Motor Proficiency (High vs. Low)	1.961	1.177	3.270*
Physical Fitness (ref group 1st Quartile)			
2nd Quartile	1.028	0.716	1.477
3rd Quartile	1.202	0.830	1.740
4th Quartile	1.808	1.226	2.667*
Parental Education (ref group high school)			
Some College	1.522	0.999	2.319
Trade Certificate	1.491	0.915	2.430
College	2.103	1.511	2.926*
Undergraduate Degree	3.064	1.965	4.778*
Professional Degree	5.932	2.563	13.729*
Graduate Degree	4.727	1.571	14.228*
N=1179			

*CI Includes does not include 1

Tables 19-21 show the independent logistical regression for the three components of overall academic performance: reading, writing, and math. Some notable differences existed across topic areas. For example, higher motor proficiency significantly increased the odds of achieving well academically for writing (OR=2.491, CI=1.469-4.224) but was not significant for reading (OR=1.218, CI=0.724-2.049) or math (OR=1.564, CI=0.939-2.605). Children with the highest physical fitness scores are at increased odds of outperforming their less physically fit peers in writing (OR=1.590, 1.076-2.349) and math (OR=1.888, CI=1.295-2.753).

Table 19 – Logistic Regression of Reading Performance (above/below provincial standards) on Age, Gender, Motor Proficiency, Physical Fitness, and Parental Education

	Point Estimate (Odds Ratio)	95% Wald Confidence Limits	
Age	0.786	0.538	1.148
Gender F vs. M	1.875	1.439	2.444*
Motor Proficiency (High vs. Low)	1.218	0.724	2.049
Physical Fitness (ref group 1st Quartile)			
2nd Quartile	0.931	0.645	1.346
3rd Quartile	1.107	0.759	1.616
4th Quartile	1.342	0.910	1.980
Parental Education (ref group high school)			
Some College	1.368	0.891	2.100
Trade Certificate	1.388	0.844	2.283
College	1.640	1.176	2.287*
Undergraduate Degree	2.345	1.504	3.657*
Professional Degree	4.701	2.032	10.873*
Graduate Degree	3.803	1.265	11.431*
N=1179			

*CI Includes does not include 1

Table 20 – Logistic Regression of Writing Performance (above/below provincial standards) on Age, Gender, Motor Proficiency, Physical Fitness, and Parental Education

	Point Estimate (Odds Ratio)	95% Wald Confidence Limits	
Age	0.842	0.574	1.237
Gender F vs. M	3.533	2.685	4.648*
Motor Proficiency (High vs. Low)	2.491	1.469	4.224*
Physical Fitness (ref score<2.5)			
2nd Quartile	1.048	0.722	1.523
3rd Quartile	1.626	1.101	2.401*
4th Quartile	1.590	1.076	2.349*
Parental Education (ref group high school)			
Some College	1.400	0.907	2.163
Trade Certificate	1.358	0.820	2.250
College	2.046	1.454	2.880
Undergraduate Degree	1.961	1.273	3.022*
Professional Degree	3.202	1.575	6.511*
Graduate Degree	10.643	2.413	46.947*
N=1179			

*CI Includes does not include 1

Table 21 – Logistic Regression of Math Performance (above/below provincial standards) on Age, Gender, Motor Proficiency, Physical Fitness, and Parental Education

	Point Estimate (Odds Ratio)	95% Wald Confidence Limits	
Age	0.759	0.523	1.101
Gender F vs. M	1.013	0.785	1.307
Motor Proficiency (High vs. Low)	1.564	0.939	2.605
Physical Fitness (ref score<2.5)			
2nd Quartile	1.103	0.775	1.569
3rd Quartile	1.489	1.037	2.137*
4th Quartile	1.888	1.295	2.753*
Parental Education (ref group high school)			
Some College	1.389	0.919	2.099
Trade Certificate	1.661	1.026	2.689*
College	2.058	1.489	2.846*
Undergraduate Degree	3.904	2.495	6.108*
Professional Degree	3.763	1.846	7.671*
Graduate Degree	7.792	2.277	26.662*
N=1179			

*CI Includes does not include 1

4.4.0 Hierarchical Linear Modeling

The final analysis conducted took a mixed modeling approach. As previously mentioned, participants were selected from 75 schools within one school district. Although standardized testing should theoretically offer equal opportunity for every student, variation may exist depending on which school students attend. Based on the design of the PHAST study, there is a natural clustering of children which violates the assumption of statistical independence between observations required for regression modeling. Due to these clusters, children in one school are apt to score similarly to their peers in the same school. Mixed modeling allows the variation between and within schools to be accounted for, something that OLS regression fails to accomplish.

As highlighted in Table 22, the school attended by the child was treated as a random effect while all other variables in the analysis were kept as fixed effects. The ability to account for random effects is what distinguishes this analysis as it now has the ability to account for between and within school variation on the EQAO standardized tests. As found in Model 4, both the within school variation (0.206) and between school variation (0.023) are significant when controlling for all other variables in the model. The variance component within schools is nearly nine times the size of the variance component between schools. Of importance for this analysis is that both physical fitness (0.011) and motor proficiency (0.002) significantly predict academic performance even after accounting for school effect along with controlling for all other variables in Model 4. The coefficients displayed in the fixed effects section of Table 22 can be interpreted in the same way as coefficients in linear regression; they reflect the expected difference in the academic performance associated with a 1-unit change in the predictor variable.

Table 22 – Hierarchical Linear Modeling of EQAO average on Age, Gender, Motor Proficiency, and Physical Fitness

Fixed effects	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Intercept	3.761 (0.406)**	3.227 (0.398)**	2.631 (0.412)**	2.309 (0.513)**
Age	-0.060 (0.034)	-0.040 (0.033)	-0.033 (0.033)	-0.016 (0.041)
Gender	0.117 (0.023)**	0.155 (0.023)**	0.175 (0.023)**	0.194 (0.028)**
Motor Proficiency	-	0.004 (0.0003)**	0.003 (0.0004)**	0.002 (0.0005)**
Physical Fitness	-	-	0.013 (0.002)**	0.011 (0.003) *
Parental Education	-	-	-	0.071 (0.008)**
Random Effects (school)				
Intercept	0.040 (0.008)**	0.035 (0.008)**	0.023 (0.006) *	0.023 (0.006) *
Residual	0.237 (0.008)**	0.223 (0.007)**	0.206 (0.009)**	0.206 (0.009)**

*p<0.05
**p<0.0001

Chapter 5: Discussion

5.1.0 Discussion

The main objective of this study was to determine the relationship between motor proficiency and academic performance while examine the potential mediating effects of physical fitness. The relationship between motor proficiency and academic performance has been previously investigated (Düger et al., 1999). Furthermore, the relationship between physical fitness and academic performance has been examined (Castelli et al., 2007; Chomitz et al., 2009). Finally, the relationship between motor proficiency and physical fitness had been previously researched (Faught et al., 2005). However, the association between academic performance, motor proficiency, and physical fitness remained largely unexplored.

The findings from this study substantiate with empirical evidence that a student's academic performance is significantly associated with motor proficiency. Further, these results also support a growing body of evidence demonstrating a significant positive relationship between academic performance and physical fitness. The key finding of this study is that physical fitness plays a partial mediating role on the relationship between academic performance and motor proficiency although both aerobic fitness and motor proficiency have an independent role in predicting academic performance. Initially it was hypothesized that physical fitness would explain why children with motor difficulties might be impacted academically. However, only partial mediation is present as motor proficiency continues to significantly and independently predict academic performance after accounting for the impact of physical fitness. Even after accounting for age, gender, and SES, motor proficiency remained a consistent predictor of academic performance. This remained true when academic performance was considered as a combined total average or when raw EQAO scores for reading, writing, and math were examined independently.

Although not the focus of this paper, it is important to speculate as to why physical fitness plays this unique role in predicting a child's academic performance. A potential mechanism to investigate is the physiological responses to exercise and a physically active lifestyle. Brain-derived neurotrophic factors (BDNF) play a significant role in the survival, maintenance, and growth of neurons (Yamada, Mizuno, & Nabeshima, 2002). More specifically, Yamada, Mizuno, and Nabeshima (2002) suggest that BDNF have an important role in learning and memory. Knowing that exercise induces increased levels of BDNF perhaps this offers a partial explanation as to why children benefit academically from a physically active lifestyle (Ferris, Williams, &

Shen, 2007). Although Ferris, Williams, and Shen (2007) examined responses specific to quick bouts of exercise, one can project the potential longer term benefits of being consistently exposed to a physical actively lifestyle. Knowing that bouts of exercise may help to enhance the survival, maintenance, and growth of neurons, it is plausible that this may translate to enhancements in the classroom. This is only one potential explanation as to why physical fitness has a positive relationship with academic performance.

It should be noted that in the regression models presented, the percent of explained variance (R^2 value) in academic performance ranged from approximately 9%-19% depending on reading, writing, or math performance was considered as the dependent variable. Looking more closely, motor proficiency and physical fitness played a small, but significant, role in explaining some of the variance in a child's academic performance. With physical fitness acting as only a partial mediator, this opens discussion for other plausible reasons why motor proficiency significantly predicts a child's academic performance.

Another probable explanation for this relationship extends to the child's social environment. As outlined by Wentzel and Wigfield (1998), a child's academic performance is influenced by their relations with peers and teachers. Wentzel and Wigfield (1998) discuss the influence of social-motivation on academic motivation and the consequences on academic performance. Unfortunately research suggests that students with low levels of motor coordination may experience social withdrawal. Smyth and Anderson (2000), who observed children in the school setting during leisure time, found that children with movement difficulties were more likely to spend time alone, spend more time watching other children play, and at some ages more likely to be disengaged from typical playground activities. Furthermore, Poulsen, Ziviani, Cuskelly, and Smith (2007) found that males with motor movement difficulties experience significantly higher loneliness as compared to their counterparts without motor difficulties. With research suggesting that children with motor difficulties experience a certain level of social isolation, there is reason to consider this as a mechanism for their struggle academically. Perhaps the construct that explains why some children socially isolate themselves can provide an explanation as to why certain children have difficulties academically. It is possible that this reasoning is embedded in the various degrees of motivation experienced by a child, for example the social and academic motivational processes outlined by Wentzel and Wigfield (1998).

The logistic regression analysis reveals that student with high motor proficiency are more likely to achieve high on overall academic performance compared to their less motor proficient peers.

However, when examining reading, writing, and math independently results differed. Writing was the only subject where motor proficient children were significantly more probable to outperform their motor deficient peers. From this study one can only speculate as to why writing scores might be more strongly associated with motor competence. As found by Rosenblum et al. (2008) children with motor difficulties have an increased time per stroke while handwriting as compared to a control group. Research has also suggested a link between handwriting and academic performance (Cornhill & Case-Smith, 1996). Hypothetically, if children have difficulty with the mechanics of writing and maintaining pace with the rest of the class, then perhaps the quality of the work will suffer when the relative amount of handwriting involved in writing, math, and reading is considered.

This study examined motor proficiency and observed its relationship to academic performance and physical fitness. As suggested by Düger et al. (1999), perhaps the various subscales of the BOTMP would provide further insight into the implications of motor proficiency on academic performance. Future research should consider investigating whether differences in fine and gross motor skills have differential effects on the relationship between academic performance, motor proficiency, and physical fitness. This may offer insight into whether certain aspects of coordination interact with physical fitness and impact academic performance as well as provide perspectives for remediation.

The results of this study have implications for healthy public policy. Past interventions have targeted school children by increasing time spent in physical education classes in an effort to positively impact academic performance (Ahamed et al., 2006; Coe et al., 2006; Donnelly et al., 2009; Sallis et al., 1999). Results reaffirm that physically fit children benefit academically which supports the notion to increase physical activity opportunities during the school day. The results of the current study suggest that interventions geared towards improving academic performance may benefit from including a motor proficiency component. Since motor proficiency has a positive relationship with academic performance, then it may be important to explore interventions, perhaps from an occupational therapist perspective, to enhance a child's motor proficiency. Furthermore, previous research has found that children with low motor coordination also have lower generalized self-efficacy (Cairney et al., 2005). When trying to decipher why motor proficiency is positively associated with academic performance, future research should consider including an academic competence or self-efficacy component as they have been previously used to predict academic performance (Harter, 1982; Bandura, Barbaranelli, Vittorio Caprara, & Pastorelli, 1996).

An interesting result from this investigation is the between school variation that exists for academic performance scores. Given that the EQAO test is a standardized test, it should theoretically limit any bias posed during assessment. Considering this information, it is important to consider what causes the variability from one school to another in terms of academic performance. There are many plausible factors contributing to this difference, for example whether the school is in a rural or urban setting, schools placing differing degrees of emphasis on preparing for the annual tests, class size, or teacher experience. To answer this question, researchers should investigate this phenomenon in efforts to establish equity both within and between schools.

With education and literacy being one of the main determinants of health (PHAC, 2010) it is important to invest in effective strategies to enhance academic performance. This research supports physical fitness and motor proficiency as contributing factors to optimal levels of academic performance. Policies should be examined to establish environments conducive to maximizing opportunities for children to succeed. This may consist of implementing interventions for children with motor movement difficulties. It is clear that certain attributes and behaviours optimize academic performance, so it is important to minimize the disparity within the population.

5.2.0 Study Limitations

The results of this study should be considered in light of the following limitations. The cross-sectional design of this study limited its capacity to establish causation as it fails to track changes over a period of time. Therefore, whether motor proficiency causes academic performance or whether academic performance causes motor proficiency is not possible to determine, although only one direction is biologically plausible. Similarly, being physically fit may cause positive academic outcomes, or perhaps children who achieve well academically are more prepared to be physically fit. Nevertheless, the cross-sectional nature of this study was able to identify significant associations between predictor and outcome variables.

A further limitation to this study is the fact that not all students completed the EQAO standardized grade 6 test. For reasons that cannot be determined, a small percentage (n=117) of students did not participate in testing. Perhaps these children were ill during the testing period or under certain circumstances students can opt out of testing. Unfortunately one is left to speculate as to how these children may have impacted the results. As seen in Tables 1-3, children who did not complete the EQAO testing scored significantly lower on the BOTMP than children who completed the testing. This suggests that the results may have been strengthened had EQAO results been available for the entire study population.

Another limitation of this study surrounded the sample characteristics. Although a representative sample of Grade 6 students in the DSBN were selected, this study population was limited to one age group, from one geographical region from schools within one school board. Consequently, results may not be generalizable to students in different regions or different school boards. However, Table 8 indicates that the percentage of students achieving at or above the provincial standard for EQAO reading, writing, and math scores is similar in Niagara to provincial results.

Finally, this study was limited in its ability to collect information on ethnicity which has been suggested to be a potentially confounding variable by past research (Patterson, Kupersmidt, & Vaden, 1990). It is important for future researchers to address this limitation and account for variation between different ethnicities.

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Appendix A

Review of studies examining the influence of motor proficiency on academic performance

Author	Design	Sample	Motor Proficiency Measure	Academic Performance Measure	Relationship
Cantell et al. (1994)	Cross-sectional	115 students (15 years old)	Motor development was established using an 11 item screening measure	School records provided scores for 6 subjects; Finnish, first foreign language, math, PE, music and drawing	AP is compromised in children with poor motor competence
Düger et al. (1999)	Cross-sectional	120 students (4-11 years old)	Bruininks-Oseretsky Test of Motor Prociency	Academic learning (school report) was used to classify students as successful or unsuccessful in AP	MP positively related to AP
Stephenson et al. (2008)	Cross-sectional	35 families	DCD screening clinic	Self-reported by parents	Experienced difficulties in AP
Wacodlo et al. (2008)	Cross-sectional	323 very preterm babies at 8 years of age	Bruininks-Oseretsky Test of Motor Prociency	Standardized test of academic performance	Low MP associated with low AP

AP – Academic Performance MP – Motor Proficiency

Appendix B

Review of studies examining the influence of physical activity and physical fitness on academic performance

Author	Design	Sample	Physical Activity/Fitness Measure	Academic Performance Measure	Relationship
Ahamed et al. (2006)	Intervention - Additional 50 min./week of PA (16 months)	288 students (9-11 years old at baseline)	Physical Activity Questionnaire for Children	Canadian Achievement Test (CAT-3)	AP not compromised despite additional time spent in PA
Coe et al. (2006)	Intervention - PE during semester one or two (55 min. class) - 1 year	214 students (grade 6 at baseline)	3-day physical activity recall (3DPAR)	Classroom grades and the Terra Nova standardized test	PE timing no effect on AP, MVPA had positive effect on AP
Donnelly et al. (2009)	Intervention - Physical Activity Across the Curriculum (90 min./week of MVPA) - 3 years	1,490 students (grades 2 and 3 at baseline)		The Wechsler Individual Achievement Test-2nd Edition (WIAT-II-A) standardized test	Significant improvements in AP scores compared to controls
Sallis et al. (1999)	Intervention - Additional 27-42 mins/week spent in PE - 2 years	754 students (grade 4 at baseline)		Metropolitan Achievement Test (MAT-6 and MAT-7)	Intervention did not have harmful effects on AP
Carlson et al. (2008)	Longitudinal – 5 years	5316 students kindergarten at baseline	Indirect – Teacher reported minutes per week spent in PE class	Standardized test for math and reading	AP for females in high PE category had small, significant benefit
Kwak et al. (2009)	Cross-sectional	232 students (9-10 and 15-16 years old)	Direct - PA measured using accelerometers for four consecutive days	Sum of classroom grades in 17 subjects	In females vigorous PA was positively associated with AP
Castelli et al. (2007)	Cross-sectional	259 students (grades 3 and 5)	Direct – Fitnessgram	Illinois Standards Achievement Test	PF positively related to AP
Chomitz et al. (2009)	Cross-sectional	1841 students (grades 4,6,7,8)	Direct - Fitness Achievement variable	Massachusetts Comprehensive Assessment System	PF positively related to AP

Table continued.

Author	Design	Sample	Physical Activity/Fitness Measure	Academic Performance Measure	Relationship
Cottrell et al. (2007)	Cross-sectional	968 students (9-13 years old)	Direct – Fitnessgram	West Virginia Educational Standards Test	Low PF related to low AP
Dwyer et al. (2001)	Cross-sectional	7,961 students (7-15 years old)	Indirect/Direct - Questionnaires and PF testing (running, sprinting, trunk flexion, push-ups, etc.)	Indicators of AP obtained from principal	PF and PA positively associated with AP
Kantomaa et al. (2010)	Cross-sectional	7,002 students (15-16 years old)	Indirect - One question regarding involvement in MVPA	Student rated performance in Finnish language, general subjects, math, and natural science	PA was associated with high AP
Pate et al. (1996)	Cross-sectional	11,631 students (12-18 years old)	Indirect - Self-reported based on two questions	Self-reported perception of AP	Low PA was associated with perception of low AP
Sigfúsdóttir et al. (2007)	Cross-sectional	5,810 students (14-15 years old)	Indirect - Self-reported based on four questions	Self-reported grades in core subjects of Icelandic, math, English and Danish	PA significant but weak predictor of AP
Daley et al. (2000)	Cross-sectional	232 Catholic students (13-16 years old)	Indirect - Physical Activity Participation Questionnaire	Classroom grades	No correlations between PA and AP, but there was a weak, negative correlation for time spent in PA and English grades
Tremblay et al. (2000)	Cross-sectional	5,146 students (grade 6)	Indirect - Self-reported based on four questions	Mathematics and reading scores	PA inversely related to AP

PA – Physical Activity PE – Physical Education MVPA – Moderate and Vigorous Physical Activity

AP – Academic Performance PF – Physical Fitness

Appendix C – Research Ethics Board Letter of Approval

DATE: January 10, 2008

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

TO: Brent FAUGHT, CHSC
John Hay, John Cairney

FILE: 07-106 FAUGHT

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

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

DECISION: Accepted as clarified

This project has received ethics clearance for the period of January 10, 2008 to December 30, 2011 subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The clearance period may be extended upon request. *The study may now proceed.*

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed and cleared by the REB. During the course of research no deviations from, or changes to, the protocol, recruitment, or consent form may be initiated without prior written clearance from the REB. The Board must provide clearance for any modifications before they can be implemented. If you wish to modify your research project, please refer to http://www.brocku.ca/researchservices/forms to complete the appropriate form Revision or Modification to an Ongoing Application.

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants and the continuation of the protocol.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research protocols.

The Tri-Council Policy Statement requires that ongoing research be monitored. A Final Report is required for all projects upon completion of the project. Researchers with projects lasting more than one year are required to submit a Continuing Review Report annually. The Office of Research Services will contact you when this form *Continuing Review/Final Report* is required.

Please quote your REB file number on all future correspondence.
MM/kw

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Appendix D – Cleaning of Data