THE INTER-RELATIONSHIPS AMONG PHYSICAL ACTIVITY, MOTOR PERFORMANCE, AND PERCEIVED ATHLETIC COMPETENCE IN NORMAL & OVERWEIGHT/OBESE CHILDREN

By

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ABSTRACT

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This dissertation examined the relative influence of body mass index (BMI), motor performance (MP), perceived athletic competence (PAC), and their interactions on physical activity participation in children. Subjects for this cross-sectional investigation were 1881 children (9.9 years; 955 boys, 926 girls) from the Niagara region of Southern Ontario who participated in the Physical Health Activity Study Team (PHAST). Physical activity (PA) was assessed using the Physical Activity Participation Questionnaire. MP was measured using the short form of the Bruininks-Oseretsky Test of Motor Proficiency. The athletic subscale of the Self-Perception Profile for Children was used as a measure of PAC. Girls had significantly lower MP abilities than boys (62.6 ± 30.4 percentile vs. 71.2 ± 29.0 percentile, $p < .001$), and significantly lower PAC scores compared to boys (17.8 ± 4.3 vs. 19.1 ± 3.9, $p = < .001$). In boys and girls, PA participation was significantly, but weakly correlated with PAC, MP, and SES but not with BMI. There was a moderate correlation between PAC and PA in both boys (.413) and girls (.420) explaining roughly 17% of the variance. Other significant ($p < .001$) but weak correlations existed between PAC and MP (.267; .224), and BMI and MP (-.316; -.237) for boys and girls, respectively. There were no significant interaction terms in the regression models. In conclusion, this study shows that PAC explains 17% of the variance in physical activity participation. Based on these findings improvements in PAC could be an important objective of physical activity interventions for children.

This dissertation is dedicated to my wife, Penelope, and my children Aidan and Audrey. Without your love, patience, sacrifice, and support I would not have been able to accomplish this goal. May my future successes in academia and our involvement in the Hope community have been worth the journey.

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CHAPTER 1: INTRODUCTION

Background. Childhood obesity is one of the top public health issues in North America (McLanahan et al., 2006; Public Health Agency of Canada, 2011). Estimates indicate that the prevalence rate has increased three-fold in the U.S. over the past few decades (Jolliffe, 2004). Currently, the prevalence of overweight and obesity among children and adolescents in the United States (U.S.) and Canada is about 32% (Ogden et al., 2014; Roberts et al., 2012). The prevalence of obesity alone is 16.9% for U.S. children and adolescents 2 to 19 years of age (body mass index, BMI $\geq 95^{th}$ centile for age and sex) (Ogden et al., 2014) and 11.7% among Canadian children and adolescents 5 to 17 years of age (Roberts et al., 2012).

Although obesity is recognized as a complex multi-factorial condition (Eisenmann, 2006), physical inactivity is a leading contributor to the development and continuation of obesity (Must & Tybor, 2005). The 2003-2004 National Health and Nutrition Examination Survey (NHANES) indicated that 58% of 6 to 11 year old children and 92% of adolescents 12 to 19 years old did not meet the recommendation for daily physical activity (i.e., minimum 60 minutes of moderate-to-vigorous physical activity per day (MVPA)) when assessed by accelerometer (Troiano et al., 2008). The mean MVPA was 95 minutes and 75 minutes for 6 to 11 year old boys and girls, respectively; however, there was also tremendous variability between individuals of different ages, ethnicities, and genders.

In addition to age, ethnicity, and gender, several other factors have also been shown to contribute to the inter-individual variation in physical activity levels among children and adolescents. These factors include but are not limited to socioeconomic status, body mass index (BMI), parental support, and geographical location (Gordon-Larsen et al., 2000; Sallis et al., 2000; Stanley et al., 2012).

Further, children who are obese (BMI >95th percentile for age & gender) demonstrate significantly lower levels of physical activity than non-obese peers throughout childhood and adolescence (Trost et al., 2001). In addition to previously mentioned factors contributing to variation in physical activity, additional factors have been cited as potential reasons for the lower levels of physical activity observed in overweight and obese children and adolescents (Stankov et al., 2012). In particular, overweight and obese children and adolescents display poor physical aptitude while dealing with developmental and psychological barriers such as poor gross motor performance, increased fatigue, low perceived competence, low physical activity self-efficacy, and reduced social support, as well increased anxiety and self-consciousness when engaging in physical activities (Epstein et al., 1996; Trost et al., 2001; Morgan et al., 2008; Stankov et al., 2012).

Among the previously mentioned factors, motor skill performance or skill-related fitness may be a key factor affecting the physical activity levels of overweight and obese children (Malina, 1991; Clark & Metcalfe, 2002). Motor skill performance can be defined as "the observable production of a voluntary action, or a motor skill" (Schmidt & Wrisberg, 2008) including running, jumping, skipping, catching, and kicking. Motor skill development has been postulated as a prerequisite to participation in lifelong physical activity. It has been deemed essential to develop a wide base of fundamental motor skills during early to middle childhood to enhance the ability to participate in physical activity, particularly in recreational sports settings (Taylor et al., 1999; Malina, 1991; Okeley et al., 2001; Clark & Metcalfe, 2002; Stodden et al., 2008). Though the contexts of physical activity (i.e., physical education classes; recreational youth sport) in childhood and adolescence are only moderately predictive of lifelong physical activity patterns (Telama et al., 2005; Craigie et al., 2011), these skill-based activities contribute a large portion of children's physical activity and may develop the impetus for activity through the lifespan.

Just as the actual performance of motor skills is important in promoting habitual physical activity throughout the lifespan, a strong perceived motor competence during childhood is also necessary. Harter (1978) suggested that children who perceive that they are competent in specific tasks and have attained mastery level performance are more likely to persist in that specific task. Therefore, children who do not master fundamental motor skills may have lower perceived motor competence and lower physical activity levels than their peers. This relationship between actual and perceived motor abilities becomes increasingly robust during adolescence (Ulrich, 1987; Stodden, 2008). Physical activity during childhood, such as physical education classes and recreational sport, prove to be invaluable in developing the foundational motor competence for lifelong physical activity (Barnett et al., 2008).

The Stodden Model and Associated Literature. In 2008, Stodden and colleagues proposed a model (see Figure 1) outlining the developmental mechanisms that may influence the physical activity levels of children and the risk of becoming overweight and obese. The central tenet of the model is the interrelated bivariate relationships between four variables: physical activity, perceived motor competence, motor competence (motor performance), and health-related fitness. The model asserts that these relationships vary during childhood. Terms with associated abbreviations, such as early childhood (EC), middle childhood (MC), and late childhood (LC) are utilized within the model to define periods of development but are not given specifically defined age ranges.

According to Stodden and colleagues, those who possess stronger perceived motor competence during early childhood will tend to develop better actual motor competence. These children will be more likely to persist when attempting a new task until mastery than a child with inadequate perceived motor competence. Children with greater perceived motor competence are also seen to possess greater levels of physical activity. Most notable in early childhood, motor competence is seen to be greater in children with increased opportunities for participation in physical education, recreational sport, and other physical activity during early childhood.

In addition, the Stodden model suggests that as a child approaches middle childhood and adolescence, poor motor competence negatively impacts perceived motor competence. Older children and/or adolescents that have not established a "strong motor repertoire" may lack the skill and confidence to participate in physical activity. Stodden and colleagues posit that the relationship between motor competence and physical activity strengthens as a child ages.

The model ultimately predicts weight status: healthy weight or unhealthy weight/obesity. Healthy weight is associated with a "positive spiral of engagement", which includes children with greater motor competence, higher perceived motor competence and higher physical activity levels. The model further suggests that unhealthy weight or obesity may be the result of a "perfect storm" of poor perceived motor competence, low motor competence, and low physical activity levels. When a child is of an unhealthy weight or obese, he or she is more likely to disengage, and participation in physical activity is suggested to decrease, which could exacerbate the weight problem.

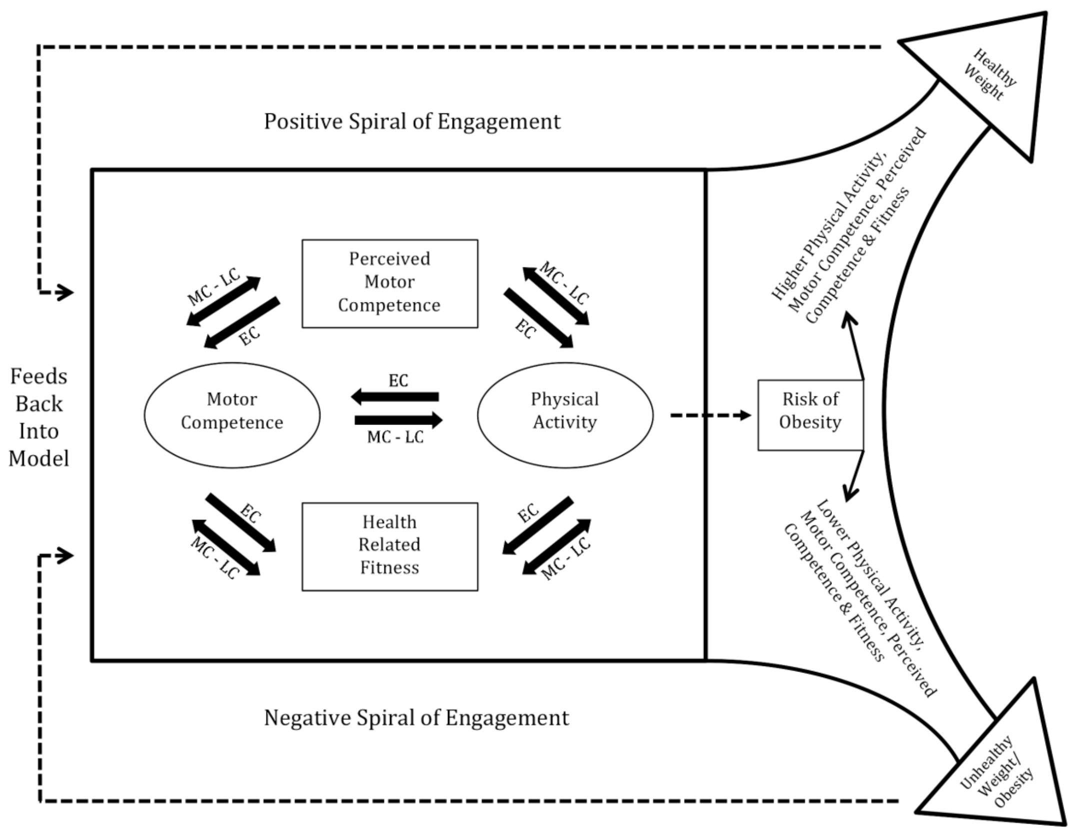

Figure 1. Adapted from Stodden and colleague's (2008) model to explain developmental mechanisms of physical activity levels of children

The Stodden model is supported by a growing body of literature addressing bivariate relationships between the variables included within it. In general, results indicate that children can self-evaluate their own motor competence poorly to moderately well ($r = 0.25 - 0.56$) when compared to measurements of actual motor competence (Ulrich, 1987; Rudisill, Mahar, & Meaney, 1993; Raudsepp & Liblik, 2002; Toftegaard-stoeckel, Groenfeldt, & Andersen, 2010). When comparing genders, boys are seen to be more physically active and have greater perceptions of competence in athletics and physical tasks than girls, but overall self-perception has a similar predictive ability ($r^2 = 0.27$ to 0.29) for physical activity in both genders (Crocker, Eklund, & Kent, 2000).

Individuals with higher levels of adiposity, or those categorized as overweight/obese, display lower physical activity levels (Gordon-Larsen et al., 2000; Sallis et al., 2000; Trost et al., 2001; Trost et al., 2003). In an evaluation of 20 studies, Must and Tybor (2005) concluded that various markers of body composition (body mass index, % body fat, etc.) have an inverse association with physical activity and have direct association with inactivity or sedentary behavior. In 2011, Colley and colleagues found that overweight and obese Canadian boys ages 6 to 19 years old performed significantly less MVPA (51 and 44 minutes, respectively) compared to normal weight boys (65 minutes). However, the relationship was not significant for girls in this sample. In summary, increased adipose tissue or unhealthy weight status seems to have inverse relationship with the physical activity levels of children and adolescents, but the relationship may not be as strong in girls.

Parallel to the differences in physical activity levels, motor skill performance of overweight and obese children tend to be deficient when compared with their normal weight peers. Body composition or weight status explains anywhere from 0 to 18% of the variance in motor performance, with larger amounts of variance being explained for weight-bearing movement tasks such as markers of agility, jumping, and running (Malina et al., 1995; Graf et al., 2004; Okely et al., 2004, Mond et al., 2007; Jones et al., 2010; Morano et al., 2011; Poulsen et al., 2011; Southall, Okely, & Steele, 2004). Given the moderate association between perceived motor competence and motor performance, it is not surprising that perceived physical competences (coordination, strength, balance, speed, agility) are all lower in overweight or obese children when compared to normal weight children (Jones et al., 2010; Poulsen et al., 2011; Southall, Okely, & Steele, 2004).

Further, motor competence and perceived motor competence have weak to moderate associations with childhood physical activity in cross sectional studies, but results are equivocal in a scarce number of longitudinal studies. Motor performance explains between 1 to 30% of the variance in physical activity (Okely et al., 2001; Graf et al., 2004; Fisher et al., 2004; Reed et al., 2004; Raudsepp & Päll, 2006; Wrotniak et al., 2006; Morgan et al., 2008; Williams et al, 2008; Barnett et al., 2009), whereas perceived motor competence explains 7 to 29% of the variance in physical activity levels of children (Roberts, Kleiber, & Duda, 1981; Crocker, Eklund, & Kowalski, 2000; Davison, Downs, & Birch, 2006).

In conclusion, previous findings suggest increasing motor performance abilities and perceived motor competence could be important correlates in combating childhood obesity through increasing physical activity levels during developmental years. More research is needed to comprehend how the combined relationship between physical performance of motor skills and perception of one's ability to perform said motor skills can impact physical activity levels during childhood. Studies including overweight and obese children are of the highest priority due to the childhood obesity epidemic.

Rationale. To the author's knowledge, only one study has analyzed the bivariate relationships between body mass index, motor performance, and perceived athletic competence and their ability, individually and through interaction terms, to predict childhood physical activity. Morgan et al. (2008) examined the bivariate correlations and ability of interactions to explain the physical activity of obese children. Object-control motor proficiency (catching, kicking, throwing) was the most significant predictor of accelerometer counts per minute (CPM) and % of observed time spent in vigorous physical activity (VPA) for boys, explaining 25% and 10% of the variance, respectively. For girls, age was the only significant predictor of moderate intensity physical activity (MPA) and VPA, explaining 38% and 15%, respectively. Independently, age explained 56% of the variance in MPA for boys in this sample.

Despite not being included in the final regression models, global performance of fundamental motor skills (gross motor quotient) explained 24% of the variance in VPA for boys and 12.3% of the variance in moderate intensity physical activity (MPA) for girls. However, BMI z-score and perceived athletic competence were not identified as statistically significant correlates of physical activity in this sample. All two-way interactions between age, motor performance, perceived athletic competence, and BMI z-score were assessed as covariates of MPA, VPA, and CPM, but none were found to be significant.

The results of this study provide support that age and motor performance could be a significant correlates of physical activity during childhood. However, the subjects in this study were enrolled in an obesity intervention and probably not representative of the general population of obese children or overall general population. Conducting a study with similar objectives using a sample that has a weight status distribution representative of the general population is warranted.

As previously identified, there are a sufficient number of studies addressing the bivariate correlations between physical activity, weight status, perceived motor competence and motor performance. One gap in the literature is a need for a multifactorial multiple regression analyses that examines the previously discussed variables simultaneously due to their unique inter-relatedness. That is, if one variable is not involved in the model, the relationship between the others is divergent. These multiple regression analyses need to be completed on a representative sample that is heterogeneous with regard to weight status, including both normal weight, overweight, and obese children, which to the author's knowledge would be novel to the literature.

Since the strength of the relationship between weight status and motor performance as well as that of weight status and perceived motor competence have been established in the literature, these correlates of physical activity are not mutually exclusive. Therefore, using the Stodden Model as a framework, the proposed analysis would be to observe how the interaction between weight status (normal vs. overweight/obese), motor performance and perceived athletic competence explains the variance of physical activity levels of children. This could provide an indication to the contribution the individual correlates and associated interactions have on variance of childhood habitual physical activity. This study could also provide necessary information for individuals working with overweight/obese children as to how the previously described "perfect storm" produces barriers to physical activity in relation to their normal weight peers.

Objectives and Specific Aims of this Dissertation

The first objective of this dissertation is to identify potential correlates (age, body mass index, motor performance, perceived competence, socioeconomic status) of physical activity in children ages 8 to 11 years of age in a main effects model.

The second objective of this dissertation is to examine how the interaction among body mass index, motor performance and perceived athletic competence explain the variance of physical activity levels in a representative sample of children 8 to 11 years of age.

The **overall objective of this dissertation** is to provide a better understanding of specific correlates (motor performance, perceived athletic competence, and body mass index or weight status) that have been associated with lower levels of physical activity levels among overweight and obese children. Further, the interrelationships among physical activity, weight status, motor performance and perceived athletic competence in children will be further examined.

These objectives will be accomplished by conducting a series of analyses on a large, representative data set. The PHAST (Physical Health Activity Study Team) project began during the 2004-2005 school year in the Niagara region of Southern Ontario. 92 schools were contacted to recruit children enrolled in 4^{th} grade for participation in the study. 75 (83.3%) of schools granted permission; informed consent was obtained from 2278 (95.8%) of 2378 children. Training and testing protocols were conducted and established during the fall of 2004 and the initial wave of data collection took place in April and May of 2005. A sample of the data from the above mentioned PHAST spring 2005 wave will be used for retrospective analyses in this dissertation. A total of 2190 children underwent assessment in the spring 2005 wave. Participants were included in the current analyses only if they has complete data for age, body mass index, motor testing, perceived athletic competence, physical activity, and socioeconomic status. There were 309 participants with missing motor performance outcomes or other essential values, which left a total of 1881 participants (955 boys; 926 girls) with complete data.

The analyses and findings will be presented within a manuscript prepared for submission contained in Chapter 3 of the dissertation. The specific aims and justification/rationale for each analysis will also be reported within the manuscript chapter. They are as follows:

<u>Specific aim 1:</u> Examine the influence of body mass index, motor performance, and perceived athletic competence on physical activity participation in normal weight and overweight/obese children and adolescents while controlling for chronological age and socioeconomic status. Due to the documented gender differences in physical activity participation and motor performance during this period of the lifespan, all analyses will be gender-specific. Based on previous literature, it is hypothesized that each of these variables will each explain greater than 5 % of the variance in physical activity with the complete model explaining 20% of variance.

<u>Specific aim 2:</u> Examine the interaction between body mass index, motor performance and perceived athletic competence on physical activity levels of children. It is hypothesized that the total variance of physical activity participation explained by this interactions model will be greater than 25%.

Format of dissertation. Details of the methodology of the PHAST study and data analyses used to achieve the specific aims are found in Chapter 3. Chapter 2 provides a literature review on topics related to childhood obesity; physical activity assessment and associated correlates; the interrelationships between physical activity, body composition, motor performance and perceived athletic competence in children; and physical activity interventions in overweight and obese children. The final chapter summarizes the overall findings of the analyses and provides insight for future studies. An appendix is also provided that summarizes an exploratory aim that was conducted based on the findings of this dissertation and the author's line of research.

Significance of the dissertation. The research from this dissertation provides evidence for the necessity of developing sufficient motor performance and resilient perceived athletic competence in the promotion of childhood physical activity. This research will identify the impact of weight status on physical activity patterns of children and identify if there are distinct differences in participation levels for children with low versus high motor performance abilities or weak versus strong perceptions of motor competence. Further, this dissertation could establish if greater emphasis should be put on physical education and other opportunities for motor skill development and/or supporting enhancement of perceived athletic competence, which could be important practices in attempting to increase the physical activity levels of young children. In particular, these findings could assist in development of strategies within multi-disciplinary intervention programs that aspire to promote greater physical activity participation in overweight and obese children.

Strengths and limitations. Although several studies have examined the bivariate correlations between physical activity, weight status, and both perceived and actual motor competence; there is a need to conduct multivariate interaction analyses due to their unique synergistic relationship of the correlates and outcome variable. Employing multivariate interaction analysis allows the relative effect of each variable to be assessed while others are held constant and also provides the ability to compare the strength of individual variables to predict the outcome (PA), which could be advantageous during intervention. This study is the first to assess the interactions between BMI, PAC, and MP in a large representative sample of children, which allows for improved generalizability to the general population and statistical power. Finally, subjects in this study were over the development age (7.9 years) that motor development abilities have been suggested to begin stabilizing and approaching the mature state (Scammon, 1930; Gutteridge, 1939). Therefore, the impact of developmental age on motor performance may have been reduced.

The proposed study is not without limitations. Despite consistent training and testing protocols there were multiple assessors conducting the measurements of anthropometric data and inter-rater reliability was not calculated. Several participants in the original PHAST study had incomplete data and were excluded from the current study, which could biased the sample assessed in this analysis. Finally, there are a variety of instruments (objective vs. subjective measure) available to assess physical activity participation of children. Instruments used to define the associated correlates (body composition, motor performance, perceived athletic competence) of physical activity also fluctuate greatly. The instruments employed to assess physical activity, perceived athletic competence, and motor performance in this study may have been well-accepted and validated, but may not have been the best to identify developmental variation.

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CHAPTER 2: REVIEW OF LITERATURE

INTRODUCTION

The habitual physical activity, motor competence and perceived motor competence of children and adolescents are all multifaceted variables that can be described and assessed with a litany of definitions and assessment tools. The relationships among the three constructs are complex and can be impacted by age, gender, biological maturity, and body composition or weight status. The primary purpose of this literature review is to provide a comprehensive review of the studies examining potential correlates of physical activity in overweight and obese youth, as well as the associations between physical activity, weight status, motor performance, and perceived motor competence. However, additional background information will be provided on the assessment and individual variation of each of the key variables, as well as additional correlates of childhood physical activity.

PHYSICAL ACTIVITY IN CHILDREN & ADOLESCENTS

Measurement of habitual physical activity in children and adolescents.

Physical activity can be defined as “any bodily movement produced by skeletal muscle that results in energy expenditure above resting levels” (Caspersen et al., 1985). Compared to adults and adolescents, the physical activity of children is often spontaneous and is composed of short discontinuous bouts of movement (Malina, Bouchard, & Bar-Or, 2004). In the classic study by Bailey and colleagues (1995), the majority (95%) of high-intensity physical activity bouts were 15 seconds or shorter in children 6 to 10 years of age. Thus, the assessment of physical activity in young children is challenging.

According to Trost (2007), the best physical activity measurement instruments should assess four major components: frequency, intensity, duration, and type. Several measurement instruments have been used to assess physical activity in pediatric populations, including direct observation, doubly labeled water, and indirect calorimetry, typically seen as criterion standards. Objective measures such as heart rate monitoring and motion sensors give discrete data on intensity and duration. Whereas, self-report measures like questionnaires and diaries allow specific bouts of activity to be identified, but depend on good recall from the participant (Sirard & Pate, 2001). These instruments vary greatly in their feasibility and validity (Welk et al., 2000); thus, choosing the right instrument consists of weighing several advantages and disadvantages (Corder et al., 2008).

Direct observation. This technique requires a trained observer to code the activities performed by a child during short intervals of time (e.g. every 15 or 30 seconds) over a specified time (e.g., 30 min, one hour), often for multiple sessions. The main difference and overall advantage when compared to diaries and questionnaires, is that this technique does not rely on subject memory or compliance (Malina et al., 2004). However, the major limitations to direct observation are that it is not feasible for large scale, epidemiologic research and requires large quantities of observer time to collect data, which increases the cost dramatically (Sirard & Pate, 2001). Another possible drawback to this method is that children may notice that they are being observed and the physical activity that they perform may change as a result, also known as the Hawthorne effect (Franke & Kaul,1978). In a study by Puhl and colleagues (1990), 16.6% of children were identified as demonstrating being “reactive” to being observed.

Two of the most commonly used observation systems are the Children’s Activity Rating Scale (CARS) (Puhl et al., 1990) and the SOFIT (System for Observing Fitness Instruction Time) (Honas et al., 2008). Both rely on five significantly distinct categories to describe physical activities performed by children; each of the five categories has been validated against indirect calorimetry and/or heart rate to insure validity. Inter-observer reliability values range from 84 to 99% for these two instruments.

Doubly labeled water. Considered the "gold standard" for field measurement of energy expenditure, doubly labeled water is seen as unobtrusive to normal patterns of activity. This method consists of a child consuming a known quantity of water that contains radioactive isotopes ($^{2}H_2$ and ^{18}O). Concentration of the isotopes in collected body fluid (e.g. urine or saliva) is measured intermittently over no more than 14 days. ^{2}H leaves body as water, whereas ^{18}O leaves the body as water or CO2. From the measurement of elimination rates of these two isotopes CO2 production can be calculated; CO2 production gives an estimate of average energy expenditure for the given period of observation (Malina et al., 2004). Major disadvantages to this method are that analyses and isotopes are very expensive and are not feasible for studies with large sample sizes (Welk et al., 2000). Further, giving the radioactive isotopes to children is ethically questionable, and it may be difficult to gain parental consent. One of the largest benefits to doubly labeled water is that it provides an accurate representation of energy expenditure, which can be used to validate other physical activity measures. However, the major shortcoming is that researchers are unable to partial out the frequency, intensity, time, or type of activity performed (Sirard & Pate, 2001).

Indirect calorimetry. Similar to doubly labeled water this method gives a precise estimation of energy expenditure; energy expenditure is calculated from measurement of oxygen consumption using a metabolic cart or another portable device. However, the major limitation of this method is that the energy expenditure of only a few specific activities (i.e. stationary cycling or treadmill running) can be assessed using the metabolic cart due to required contact with the system (Malina et al., 2004) Advances have been made with the development of portable "backpack" type units, however children do not withstand wearing these devices under long-term free-living conditions very well (Sirard & Pate, 2001). Welk and colleagues (2002) also believe that this method is not feasible to use with children due to its invasiveness and relatively high cost. However, this method can serve as accurate reference to validate objective and subjective measures in small sample sizes (i.e. n = <50).

Heart rate monitoring. This technique utilizes telemetry monitoring systems and relies on the assumption that HR is linearly related to oxygen consumption. This relationship is unique for each individual and should be calibrated using both heart rate telemetry and calorimetery in a laboratory setting (Malina et al, 2004). Using the heart rate values recorded throughout the day a researcher can estimate energy expenditure. One shortcoming of this method is that heart rates below120 beats/minute are not considered valid estimates of moderate intensity physical activity. Additionally, children are engaged in low intensity activities during the majority of their day. Therefore, a threshold heart rate for each individual is suggested (Rowlands et al., 1997; Trost, 2001). Further, at low intensities heart rate can be influenced by several factors including: ambient temperature, emotional state, caffeine intake, and muscle mass recruited for movement (Sirard & Pate, 2001; Trost, 2001). However, heart rate monitors are user-friendly, inexpensive, and provide a good estimate of the frequency, intensity, and duration of physical activity under free-living conditions (Welk et al., 2002).

Maffeis et al. (1995) concluded that heart rate monitoring, using a common Polar device, showed no significant differences to values of energy expenditure obtained from one week of doubly labeled water consumption in non-obese children. However, obese children demonstrated

6.2% greater energy expenditure using heart rate monitoring compared to doubly label water. Van den Berg-Emons and colleagues (1996) conducted another comparison of these two methods and found a strong correlation (r = .88), demonstrating the heart monitoring is a fairly valid assessment of physical activity and energy expenditure.

Motion sensors. Pedometers and accelerometers both can give fairly accurate values for the quantity of physical activity performed. Pedometers are fairly inexpensive compared to accelerometers, but cannot easily be used for predicting energy expenditure. The only variable assessed by pedometers is total volume of activity (Welk et al., 2000). Rowlands and colleagues (1997) discussed the reliability of pedometers when compared to a calibrated treadmill; depending on intensity deviations of up to 88.8% existed for the pedometer output when compared against the distance actually walked on the treadmill.

Accelerometers are considered to provide more accurate assessments of physical activity due to the fact that they measure frequency, duration, and intensity. These sophisticated instruments assess accelerations caused by increased movement associated with locomotion (Malina et al., 2004). Accelerometers are not free from drawbacks; some disadvantages include: inability to assess aquatic activities (although newer models are now water resistant or waterproof), inability to assess the change in load carrying (e.g. backpacking), participant placement problems, and the fact that the quantity of data is quite cumbersome (Welk et al., 2002). Trost et al. (2005) identified several studies demonstrating the validity of accelerometers. Further, Sirard and Pate (2001) reported strong positive correlations (r = .66-.95) between accelerometer output and energy expenditure assessed by indirect calorimetry. Sallis et al. (1990) reported the test-retest reliability of the *Caltrac* accelerometer, between left and right legs, to be r

= .89. Similar results (r = .87) were obtained by Trost and colleagues (1998), when assessing the reliability of the *CSA Actigraph* accelerometer. Accelerometers are continually becoming more and more sophisticated; Trost (2007) believes that accelerometers are one of the most promising tools for the assessment of physical activity in children. However, some issues with measurement accuracy and psychological stigmas have been reported when using accelerometers with overweight and obese youth (Robertson et al., 2011).

Diaries. This method is not regularly used to assess the physical activity of children due to the burdensome requirement of logging activity at specific intervals (e.g. 15 minutes, 1 hour) throughout the day (Sirard & Pate, 2001). It is also hypothesized that diaries may change the spontaneity of physical activity in children, decreasing validity of the measure (Malina et al, 2004). However, activity type, duration, frequency and intensity can be assessed from this instrument. Each physical activity corresponds to an estimated MET intensity; these values can be put into equations to estimate energy expenditure for the duration assessed (Welk et al., 2002). Corder et al. (2008) demonstrate that when comparing subjective recall data to objective measures such as accelerometery or heart rate monitoring, correlations range from r = .20 to .50.

Questionnaires. Ranging from paper and pencil surveys to interviewer-administered batteries; these instruments are used to assess physical activity by frequency, intensity, type, and duration. Again using estimated MET intensity for each physical activity, energy expenditure can be estimated. Questionnaires are commonly used in epidemiological studies with large sample sizes; they are low cost and fairly simple to administer. However, some researchers have been concerned with the ability of children to accurately recall the physical activity they performed (Welk et al. 2000, Welk et al., 2002). Instruments assessing physical activity within a short duration of elapsed time are believed to have the greater accuracy of report. For instance, Weston et al. (1997) obtained a strong positive correlation (r = .88) to *Caltrac* accelerometer data when using the Previous Day Physical Activity Recall (PDPAR) in children. However, Corder et al. (2008) demonstrated that when comparing questionnaire recall data to objective measures such as accelerometery or a criterion standard like doubly labeled water, correlations are weak to moderate, ranging from r = .15 to .50.

Recently, the National Institutes of Health established an expert panel to assess the validity of self-report physical activity instruments. The panel indicated that self-report measures should be carefully chosen based on a framework that addresses “purpose for assessment, physical activity constructs of interest, and characteristics of the population.” Circumstances when it is deemed favorable to use self-report measures include: evaluation of historical physical activity patterns, ranking physical activity participation levels, and for larger epidemiological studies where cost of objective devices is not feasible. Self-report measures should also possess some, if not all, of the following sources of validity evidence: test content, response processes, behavioral stability; relations with other variables; and sensitivity to change (Mâsse & de Niet, 2012; Troiano et al., 2012).

The Physical Activity Participation Questionnaire (PAQ) is a 63-item self-report questionnaire that seeks to assess the participation levels of children in free-time play, intramural school sports, community and club sports teams, as well as all other organized physical activities recalled from the previous year. Higher PAQ scores indicate a greater number of “activity units”. The total score ranges from 0-45 with a free-play index from 0 to 16 and an organized-activities index from 0 to 29. Free-play is assessed by recalling typical activity choices and organized activities catalog participation in organized athletic and competitive activities over the previous year.

Two-week test-retest reliability of the PAQ among elementary schoolchildren has been found to be r = 0.81. The PAQ has also has shown strong correlation (r = 0.62) to teacher evaluation of activity participation; however, it has not been validated against an objective measure of physical activity. Further, the instrument has good construct validity with expected differences between genders and between individuals living in different geographic locations (urban vs. rural). On the whole this instrument provides an appropriate and effective measure to compare habitual physical activity participation across a representative sample of children.

Conclusion. Overall, the instruments available to assess the physical activity of children vary greatly in their feasibility and validity. As previously stated no instrument sufficiently measures all aspects of physical activity. Therefore, until more sophisticated techniques are available to researchers, it is suggested that, if possible, multiple instruments be utilized to adequately evaluate all of the components of physical activity behavior in children (Trost, 2007).

Physical activity levels in children.

Currently, two surveillance systems exist to provide physical activity levels of nationally representative samples of children in the United States - the Youth Risk Behavior Surveillance System (YRBSS) and the National Health and Nutrition Examination Survey (NHANES). The Canadian Health Measures Survey (CHMS) is a comparable, nationally-representative, surveillance system evaluating health markers of children in Canada.

The YRBSS is a surveillance system conducted by the Centers for Disease Control (CDC). This survey includes items seeking information about health-related topics such as drug and alcohol use, sexual activity, viewing time of television, as well as seven physical activity items. Annually, approximately 14,000 to 16,000 high school aged students complete the YRBSS. Results from the 2005 YRBSS (Eaton et al., 2006) reported physical activity levels in respect to two sets of guidelines. The first guidelines were from the CDC's Healthy People 2010, which stated that children and adolescents should participate in at least 30 minutes of moderate intensity activity on at least 5 of 7 days of the week or in at least 20 minutes of vigorous activity on at least 3 of 7 days of the week. When using these guidelines, 68.7% of participants were considered to be participating in adequate physical activity.

However, the second guidelines created by an expert panel formed by the CDC (Strong et al., 2005) were considered to be more stringent. These guidelines stated that beginning in kindergarten, children should participate in at least 60 minutes of moderate to vigorous physical activity on at least 5 of 7 days of the week. When considering these guidelines, only 35.8% of the participants were considered to be participating in adequate physical activity. It is noteworthy to mention that the 2005 YRBSS results also showed that 9.7% of participants participated in no physical activity. These findings helped contribute to the establishment of 2008 PA Guidelines for Americans.

The results of the following YRBSS were reported using the 2005 Strong et al. guidelines as a reference point. In the 2007 results there was little change from 2005 with 34.7% of participants meeting the physical activity requirements of at least 60 minutes of moderate-to - vigorous physical activity on at least 5 of the previous 7 days. However, those meeting physical activity recommendations rose to 37.0% in 2009 (Eaton et al., 2010) and 49.5% in 2011 (Eaton et al., 2012). However, the 2007 YRBSS (Eaton et al., 2008) results also reported that the number of participants reporting no participation in physical activity in the previous week soared to nearly 25% with declines to 23.1% and 13.8% in the 2009 and 2011 results (Eaton et al., 2010; Eaton et al., 2012).

The NHANES surveillance system is a surveillance system that assesses various aspects of health and wellness, including dental hygiene, body composition, blood pressure, as well as physical activity. In January 2008, objectively (accelerometer) measured physical activity data from 2003-2004 NHANES were published. Using the 2005 Strong guidelines, results indicated that only 42% of 6 to 11 year old children met the recommendations for physical activity; whereas only 8% of adolescents met the same standard (Troiano et al., 2008). When assessing 2009-2010 NHANES data, 70% of 6 to 11 year old children met the same recommendation for daily physical activity when an adult completed a proxy report of their habitual physical activity (Fakhouri et al., 2013).

Finally, the 2007-2009 CHMS (Colley et al., 2011) reported that only 6.7% of Canadian children and adolescents 6 to 19 years of age completed 60 minutes or more of MVPA on 6 or more days. The percentage of boys (9%) meeting this criterion was significantly ($p<.05$) greater than girls (4.1%). When using the 2005 US guidelines to appraise the data, 16.6% of the population met the criteria, with a higher prevalence of meeting guidelines for boys (21.5%) ($p<.05$) than girls (11.3%). These figures indicate that Canada just like the United States has a great need to increase the percentage of children meeting guidelines for physical activity participation. Some variance in physical activity could in part be explained by differences in measurement and/or accelerometer cut points.

Inter-individual variation in physical activity.

As previously mentioned, several factors have been identified that contribute to the inter-individual variation in physical activity levels among children including, but not limited to age, biological maturity, ethnicity, gender, parental support, self-efficacy and socioeconomic status (Sallis, Prochaska, & Taylor, 2000; Stanley, Ridley, & Dollman, 2012; Van Der Horst et al., 2007). Further, Stankov, Olds, and Cargo (2012) examined the barriers to physical activity specifically in overweight and obese adolescents. Several factors related to the school victimization and mental health were apparent and reflects the influence weight status not only has on physical activity participation, but also the social interactions of adolescents. Establishing a better understanding of the barriers to physical activity in this population could support the development of effective interventions that promote a more active lifestyle.

Age, biological maturity, and gender. The decrease in physical activity with increasing chronological age is marked (Belcher et al., 2010; Caspersen, 2000; Eaton et al., 2006). When examining data from the 2005 YRBSS there are noticeably more students that are considered inactive (i.e., did not participate in at least 60 minutes of physical activity increasing their heart rate and making them breathe hard some of the time on at least 1 day during the 7 days before the survey) at the start of high school than at completion. Overall, prevalence was higher among 11th-graders (14.7%) and 12th-graders (15.6%) than 9th-graders (11.2%) (Eaton et al., 2006). These findings were identical when looking at data from the 2011 YRBSS (Eaton et al., 2012). Belcher and colleagues (2012) also observed significant reductions in objectively measured physical activity across ages groups (6-11, 12-15, and 16-19-year olds) when analyzing data from NHANES 2003-2004 and 2005-2006. It can be concluded that a noticeable increase in physical inactivity is present as chronological age increases, but is dependent on the definition of physical activity participation and/or inactivity.

Assessing the individual timing and tempo of biological maturation can make assessing changes in physical activity patterns across time challenging. However, the body of evidence suggesting that maturational status impacts physical activity patterns during adolescence is equal to that stating that there is no significant influence from biological maturity (Sherar et al, 2010). A study by Drenowatz and colleagues (2009) found that pedometer counts in girls 10- to 12-year-olds were significantly lower in early maturing girls compared to average and late maturing girls. However, after controlling for weight, these results did not persist, which indicates that maturity status impacts physical activity in this specific population, but the relationship is attenuated when controlling for body mass. Further research (Sherar et al., 2009; Wickel et al., 2009) strengthens the previous argument that activity levels decrease in both boys (9- to 14-year olds) and girls (8- to 16-year-olds) as chronological age increases. However, these studies did not find significant differences in daily moderate-to-vigorous physical activity when comparing accelerometer data by maturational status.

Discrepancies in physical activity participation between genders have also been documented. When comparing gender-specific data from the 2011 YRBSS (Eaton et al., 2012) the null participation in leisure time physical activity was more frequently observed among female (17.7%) students than male (10.0%) students. NHANES 2003-2004 and 2005-2006 data also demonstrated that regardless of ethnicity, age or weight status, boys recorded significantly higher average physical activity counts per minute compared to females (Belcher et al., 2010). In a study specifically examining overweight children attending weight loss camps or university-based centers, Zabinski and colleagues (2003) found that overweight girls reported higher body-related barriers to physical activity than overweight boys and indicated body consciousness and concern about others seeing their bodies while being active as the most common type of barrier to physical activity. Participation levels in higher intensity physical activities, particularly vigorous intensity and above are also generally lower in girls than boys (Sallis, Zakarian, Hovell, & Hofstetter, 1996, Trost et al., 2002). The previous highlighted literature comparing physical activity between genders confirm that boys typically display lower levels of inactivity, record higher daily participation totals, and face fewer barriers to participation than females. Interventions attempting to increase the physical activity participation should give special attention to unique needs of the female child and adolescent.

Ethnicity and socioeconomic status. Stankov, Olds, and Cargo (2012) have stated that the potential implications socioeconomic status and ethnicity could have on the physical activity participation have been poorly considered in the literature. However, the rates of inactivity have been documented to be highest among minority youth, especially females (Saxena, Borzekowski, & Rickert, 2002). The 2011 YRBSS data highlight that 13.8% of all students were considered inactive (i.e., did not participate in at least 60 minutes of physical activity increasing their heart rate and making them breathe hard some of the time on at least 1 day during the 7 days before the survey). When comparing students in gender-specific ethnicity groups, inactivity was highest among Black females (26.7%), followed by Hispanic females (21.3%) and then White females (13.7%). Males had lower prevalence, but a similar trend with Black males (12.3%) being highest, followed by Hispanic males (10.7%) and then White males (8.5%) (Eaton et al., 2012). Contrary to these findings objectively measured physical activity data from NHANES 2003-2004 and 2005-2006 (Belcher et al., 2010) demonstrated that despite decline with increasing chronological age that Non-Hispanic Black children participated in greater MVPA than Mexican American children and that Non-Hispanic White children participated in the lowest amounts of MVPA across all age groups. Further investigations making comparisons on the physical activity participation of children and adolescents from various ethnicities in specific geographic areas is warranted. These investigations would help clarify if there is a need to design interventions to target specific ethnicities or assess of the effectiveness of previous efforts.

Due to lack of financial resources to purchase equipment, transportation issues, and other barriers, children and adolescents from low socioeconomic status families may have lower opportunity to participate in physical activity than those from middle- or high-SES families (Sallis, Prochaska, & Taylor, 2000). Woodfield and colleagues (2002) assessed the physical activity levels of 301 children and adolescents (12.9 (.81) years) by 4-day physical activity recall. Results indicated that children from high socio-economic status families reported significantly ($p < .01$) higher average daily activity levels children of low socio-economic status. However, Telama and associates (2009) concluded that family socioeconomic status measured by father's education level was not related to participation in either unorganized free play or school organized physical activity during the 28 year study period. However, participation in organized youth club sport was strongly associated family socioeconomic status. Thus children from families with higher socioeconomic status participated more than those from low socioeconomic status. Thus, youth sports clubs, programs and interventions geared toward increasing physical activity should be aware of the financial restrictions that some families face and should provide participation fee waivers, scholarships, access to public transportation and equipment whenever possible to eliminate barriers to participation.

As demonstrated in the previously discussed literature, significant barriers may be present that preclude some children from participating in adequate physically activity compared to their peers. Purposeful actions should be taken to address these factors whenever possible. If the discrepancies in physical activity participation between genders, ethnicities, and individuals from lower socioeconomic status are ignored the participation gap will become ever widening.

CHILDHOOD OBESITY

Prevalence of overweight and obese children in the United States.

Childhood overweight and obesity are recognized by an abnormally high body mass index (BMI) at for a given age and gender. BMI is a common measure expressing the ratio of weight-to-height. It provides an indication of the appropriateness of a child's weight relative to height, but does not estimate the percentage of fat (Cooper Institute for Aerobics Research, 2005). BMI is found by computing the following formula: weight (kg) / height squared (m^2), and it increases as a function of biological growth from infancy through childhood to adolescence.

The Centers for Disease Control and Prevention (CDC) define overweight and obesity using age- and sex-specific BMI percentiles. An adult who has a BMI between 25 and 29 kg/m^2 is considered overweight, while an adult who has a BMI of 30 kg/m^2 or higher is considered obese. For children and adolescents, high BMI scores are also referred to as overweight and obese. Unlike BMI ratios for adults, calculations for children and adolescents take into account the differences in maturational timing and tempo between boys and girls, as specific BMI-for-age calculations are used (Defining and Diagnosing Obesity, 2005). BMI-for-age is plotted on a growth chart that determines in which percentile a child or adolescent's score falls. According to a report which included over 300 studies related to the assessment of child and adolescent overweight and obesity, the CDC 2000 growth charts provide the best reference data available for the growth of children in North America (Krebs et al., 2007). The CDC developed charts for boys and girls from birth to age 20 for BMI, height, and weight percentiles (CDC, 2009). Data on White, Black, and Mexican American children and adolescents in the United States was used to develop the CDC BMI-for-age growth charts (Guo, Wu, Chumlea, & Roche, 2002). The weight status category as determined by the BMI-for-age percentiles for children and adolescents is shown in Table 1.

Table 1. CDC weight status category by BMI-for-age percentiles of children and adolescents

Weight Status Category	Percentile Range
Underweight	Less than the 5th percentile
Healthy Weight	5th percentile to less than the 85th percentile
Overweight	85th percentile to less than the 95th percentile
Obese	Equal or greater than the 95th percentile

The CDC changed this terminology in 2005 from "at-risk for overweight" if the BMI of the child/adolescent fell between the 85th and 95th percentile for their age and gender, and "overweight" if the BMI of the child/adolescent was equal or greater to the 95th percentile for their age and gender. This change resulted from the seriousness, urgency, and medical nature of childhood obesity, and the unsuccessful attempts to take action on the issue (Krebs et al., 2007).

The American Academy of Pediatrics recommends that physicians calculate and plot BMI-for-age once a year for all children and adolescents and monitor change to assess those that are overweight or obese (Defining and Diagnosing Obesity, 2005). A committee of pediatric obesity experts recommended that children with a BMI greater than or equal to the 85th percentile (with complications of obesity) or greater than or equal to the 95th percentile (with or without complications of obesity), undergo evaluation and possible treatment and that treatment begins early, involves the family, and includes permanent changes (Barlow & Dietz, 1998).

Data from the National Health and Nutrition Examination Survey (NHANES) have documented the prevalence rates and the change in the prevalence of US children between the ages of 2 and 19 from 1971 to current. Between 1971 and 1974, the prevalence of overweight children in the U.S. was 15.3%**.** With an 86% increase over 25 years, this value rose to 28.4% between 1999 and 2000. The most startling statistic is that the prevalence of US children considered obese showed an increase of 182% during this time period with the prevalence rising from 5.1% to 14.4% (Joliffe, 2004).

Prevalence estimates by Ogden et al. (2006) identified that these trends continued to increase at an alarming rate in this population. Data from NHANES (2001-2002) identified the prevalence of US children considered overweight or obese were 30.0% and 15.4%, respectively. Higher prevalence was observed among Non-Hispanic blacks and Mexican Americans. Reporting in 2008 (Ogden et al., 2008) gave some hope that the epidemic might have stabilized as there were no significant differences observed for the prevalence reported in the NHANES 1999-2004 compared to the NHANES 2003-2006 data. Further, the 2003-2006 prevalence for overweight children 2 to 19 was 31.9% and for obese children was 16.3%. 2009-2010 data suggest continued maintenance, as prevalence of overweight was 31.8% and obesity was at16.9% (Ogden et al., 2012). Currently, the prevalence of overweight and obesity among children and adolescents in the United States (U.S.) and Canada has plateaued at 32%. The prevalence of obesity alone is 16.9% for U.S. children and adolescents 2 to 19 years of age (Ogden et al., 2014) and 11.7% among Canadian children and adolescents 5 to 17 years of age (Roberts et al., 2012). Statistical reports in 2009-2010 for overweight prevalence were almost identical in Canada at 31.5%; however, obesity prevalence was lower at 11.7% in a nationally-representative sample of 5- to 17-year olds (Roberts et al., 2012). Despite the observation that the epidemic may have reached its max point, there is still an urgent need to intervene and improve the health of individuals suffering from the multi-factorial condition.

Health risks associated with childhood obesity.

In his review of the health consequences of childhood obesity, Daniels (2006) highlighted that the increasing prevalence and severity of the disease may increase the chance that today's children will have shorter life expectancy than their parents. The author also indicated that co-morbidities of obesity once thought to be present only in obese adults are beginning to be observed in children. Examples of these co-morbidities include, but are not limited to sleep apnea, elevated blood pressure, type 2 diabetes, nonalcoholic fatty liver disease, and hardening of the cardiovascular vasculature associated with development of cardiovascular disease.

Various studies have also examined the long and short-term psychosocial consequences of childhood obesity. These consequences include negative self-image, decreased self-esteem, anxiety, eating disorders, poor socialization in peer groups, and lower health-related quality of life (Strauss, 2000; Davison & Birch, 2001; VanderWal & Mitchell, 2011). Davison and Birch (2001) note that overweight children experience reduced capacity across a number of domains of self-concept. In their study examining the relationship between weight status and self-concept in a sample of preschool-aged girls, they found that as early as age 5 years, lower self-concept is noted among girls with higher weight status. The disparities in mental health between children based on weight status are alarming and addressing them should be an essential component in prospective intervention programs.

The co-morbidities associated with childhood obesity have also led to an annual estimated expenditure of 14.1 billion dollars on supplementary healthcare, which includes services such as obesity-specific pharmacotherapy as well as emergency room and outpatient visits due to weight-related issues (Trasande & Chatterjee, 2009). These startling statistics indicate the importance of reducing the prevalence of childhood obesity must remain at the forefront of the public health agenda.

MOTOR SKILL DEVELOPMENT DURING CHILDHOOD

Historical aspects of the study of motor development.

Over the last 225 years, the field of motor development has been built upon a foundation of observations, paradigms, and theoretical frameworks that have sought to explain the progression of human locomotion and performance of various movement skills throughout the lifespan. Clark and Whitall (1989) divide and explain this duration of time in four distinct periods - Precursory, Maturational, Normative/ Descriptive, Process-oriented period.

The first 150 years of motor development research were known as the Precursor period (1787-1928). This period focused mainly on recounting observations of human development and improving the available instruments by which to study these events.

During the Maturational period (1928-1946), the principal focus was to explain how biological maturation was the primary determinant of development and illustrate the developmental sequences of various motor skills over the course of the childhood. The publication of several key papers took place during this period. These papers include but are not limited to: H.M. Halverson's (1931) description of infant prehension; Myrtle McGraw's (1935) twin study, introducing the concept of "critical periods" in the development of motor skills; Nancy Bayley's (1935) interpretations of the developmental processes of motor behavior from birth to age three; and Monica Wild's (1938) description of the patterns of over-arm throwing.

The Normative/ Descriptive period (1946-1970) was characterized by the development of several instruments to assess differences in motor performance abilities and anthropometric variables. G. Lawrence Rarick, Ruth Glassow, and Anna Espenschade are specifically noted for contributing detailed descriptions of motor performance abilities of children during this period. Additionally, it is important to mention that in 1967 the Motor Performance Study was started by Dr. Vern Seefeldt at Michigan State University; this study provided an invaluable resource to the developmental sequence paradigm, which will be described in further detail.

The Process-oriented period (1970 to present) has been marked by the establishment of theoretical frameworks attempting to explain the causal mechanisms or "processes" behind the development of motor skills, instead of focusing solely on the "product", as the majority of previous motor development research has. Two major process-oriented theories that have provided tremendous application to the study of motor development are the dynamic systems theory (Berstein, 1967) and Newell's Model of Constraints (Newell, 1986).

Description of the frameworks of motor development.

Two of the most notable sources for the developmental sequences paradigm are Michigan State University (Branta, Haubenstricker, & Seefeldt, 1984) and the University of Wisconsin (Halverson, 1966). Both of these research groups provided physical descriptions of ten fundamental motor skills; both locomotor (running, jumping, hopping, galloping, and skipping) and object-manipulative (throwing, catching, kicking, striking, punting). Intra-skill developmental sequences of these skills are considered linear and proceed in an ordered fashion from least to most mature; each stage has qualitatively different characteristics. As a child increases in biological age, there are "age-related, but not dependent" stages under which a “typical” child’s” performances will fall (Branta, Haubenstricker, & Seefeldt, 1984). Skills are also seen to possess an intra-skill sequence, which means that one skill maybe dependent on another skill reaching a critical level in order for initiation of development. For instance, the skill of skipping does not usually begin being expressed until hopping has reached stage three of four and running has reached its most mature form.

The major difference between the two developmental sequences models is that the model developed at MSU assessed skills from a whole body or composite approach, whereas the UW model gave individual components of the body (arms, legs, and trunk) specific characteristics for each stage, known as segmental sequence. Therefore, when transitional periods between intra-skill stages take place the labeling of the stage is different. For instance, if a child is beginning to progress from stage 1 to 2 of throwing and all but one component of the skill was present for stage 2, MSU would label this stage as 1+/2-, whereas the UW method would be to label this profile as 2-1-2.

In contrast, theories from the ecological perspective value the interconnectedness of the individual, environment, and task. A commonly used ecological theory used to interpret the development motor behavior is that of the dynamical systems theory. Built on the ideas of Nikolai Bernstein, dynamical system theory posits that interaction between the various systems of the body constraints or encourages a movement behavior (Haywood & Getchall, 2005). Bernstein (1967) believed that if an individual could “master the degrees of freedom” associated with a task, performance was to be expected and child would be able perform the given task.

From Bernstein’s original writings, Kugler, Kelso, & Turvey (1982) introduced a new approach for explaining the development of motor behaviors. Dissimilar from developmental sequences, dynamical systems views development as nonlinear and discontinuous. Multiple influences (growth, maturation, balance, teaching, cognitive understanding, strength, etc.) "determine the rate, sequence, and extent of development" of a particular skill (Gallahue & Ozmun, 2002, pg. 28). Dynamic systems theory revolves around one central premise that one component will induce a change in other components, which will result in a completely novel and unique behavior (Thomas, 2005).

In contrast to development sequences, Thelen and Smith (1994) state that dynamic systems theory conceptualizes that "development does not consist of the child progressing toward a known conception of adulthood." Each child will attain specific motor milestones at various rates, in differing sequences and to different extents. The attainment of motor milestones is dependent on self-organization of basic components interacting to produce higher-order products (Lewis, 2000).

As the model of dynamical systems illustrates (Figure 3), influence from factors of the task, individual, and environment will determine these processes. When utilizing dynamical systems theory, it is not as important to study the product of motor development, as it is to have a comprehension of the processes which developed the product. The two processes that help progression or cause regression in the development of a skill are known as rate limiters and affordances (examples below). Rate limiters are constraints from various systems that hold back development, whereas affordances are positive influences from the task, individual, and environment that encourage the development of a new skill form (Gallahue & Ozmun, 2002). No one factor has more influence than another factor; factors work in concert to develop a preferred behavior specific to the existing context and needs (Thelen, 1989).

Control parameters are conditions that develop a need for modification of a child's preferred movement pattern; specifically they are the "variables that provide a condition for a pattern change" (Gallahue & Ozmun, 2002). Motor patterns are not demanded to change, but when factors from the task, individual, and environment provide sufficient stimulus, the usual response is to develop the preferred movement pattern for the given situation. When a child progresses from using one form of a movement pattern to another form, this is denoted as a phase shift. Phase shifts are characterized as moving from an attractor state, or period of stable performance, into a transitional pattern of unstable and unfavorable movement. A phase shift is completed with the development of a new pattern of movement that meets the demands of the situation and performance is in a new attractor state.

Due to the vast majority of neurological development (roughly 90%) taking place in the first eight years of life, phase shifts are numerous from birth to age five (Thelen & Smith, 1994). Infancy, which typically includes the transition from one form of locomotion to another (e.g. creeping to crawling; crawling to walking) is the most significant time for these modifications (Gallahue & Ozmun, 2002, Haywood & Getchall, 2005).

When utilizing the dynamic systems approach three major components are essential to define:

- The task: Demands of the skill, degrees of freedom, movement pattern formation
- The individual: perceptual-motor factors, mechanical factors, physiological factors, anatomical/growth factors
- The environment: Opportunity for practice, encouragement/motivation, instructional cues, context of the environment

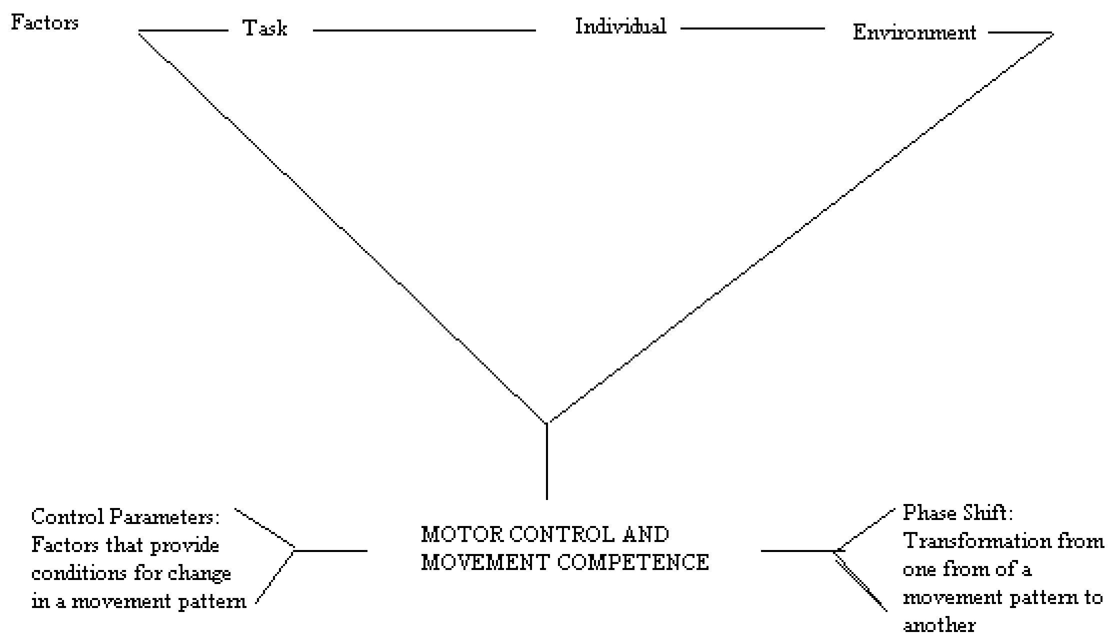

Figure 2. Dynamic systems model

Another framework developed from the ecological perspective is Newell's model of constraints. Very similar to dynamic systems theory, Newell (1986) believed that development of motor behaviors was a product of interactions between the individual, task, and environment, not dependent on predetermined linear processes. Further, both suggest that that if any of the components of these interactions are changed, the result will be a change in the motor behavior outcome (Haywood & Getchell, 2005). However, dynamical systems holds that control parameters must provide the stimulus for a movement pattern to complete a phase shift. Instead, Newell hypothesizes that the movement constraints continually work to progress a movement behavior toward a more complex form.

Several other differences and similarities between Newell's model and the developmental sequences and dynamic systems frameworks exist. Constraints in Newell's model are not to be seen as encouraging or discouraging to the development of movement skills; whereas in dynamic systems theory constraints were only seen to hold progression back. Similar to beliefs surrounding developmental sequences, Newell's model denoted certain movement skills may be limited by constraints in order to allow for the progression of other movement skills (Haywood & Getchell, 2005). As mentioned previously, these constraints come from sources associated with the task, environment, and individual. However, when comparing dynamic systems theory and Newell's model, Newell gives greater distinction between types of constraints. For instance, individual constraints are broken down into two classifications: structural or functional. Individual structural constraints are genetically influenced and focus on the individual's anatomical and physiological characteristics. Functional individual constraints are associated with psychological factors such as cognitive understanding, attention, or fear. Further, environmental constraints are categorized as factors that influence the physical environment such altitude, temperature, and lighting, or as socio-cultural factors which may influence participation based on gender, age, or religious beliefs. Finally, task constraints are associated with the equipment, rules, and goals of the desired behavior.

Assessment of motor performance.

Various instruments exist to assess fundamental motor skill performance. These instruments may be process assessments or product assessments. Process assessments, such as the Test of Gross Motor Development-2nd Edition (TGMD-2; Ulrich, 2000) or the Get Skilled: Get Active motor skill assessment tool (Okely & Booth, 2004), measure the developmental stage or level of motor skill performance on the continuum of skill maturity. Product assessments, such as the Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978) or The Movement Assessment Battery for Children (Henderson & Sugden, 1992) quantify the skill performance by the skill execution outcome, such as time, distance, or successful attempts. These two types of measurement determine the physical competencies of youth and be compared against established norm reference data.

Although process-oriented assessments can identify the specific skill components that need improvement (Ulrich, 2000); these batteries require a component assessment approach, which is considering the movement of each of the four limbs of the body simultaneously. This technique requires significant understanding of motor development and extensive training; it also can be difficult and time consuming in large samples. On the other hand, product-oriented assessments are quick, pass-fail tasks that provide quantitative feedback of a child's motor performance (Payne & Isaacs, 2008).

The short form of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP-SF) (Bruininks, 1978) is a product-oriented standardized test to assess fine and gross motor skills for children between the ages of 4 and 21 years. The short form of the test has shown strong validity (r = .90-.91) when compared against the long form in children ages 8 to 14. The BOTMP-SF consists of 14 items from all 8 subtests of the complete form which include: standing on the preferred leg on balance beam, walking heel/toe on a balance beam, tapping feet while making circle with fingers, jumping up and clapping hands, standing broad jump, catching a tossed ball with both hands, throwing a ball at a target with the preferred hand, running speed and agility (shuttle run), response speed, drawing a line through a straight path with preferred hand, copying a circle with preferred hand, copying overlapping pencils with the preferred hand, sorting shape cards with preferred hand, and making dots in circles with preferred hand. The Total Motor Composite is the sum of all 8 subtest standard scores.

Cools and colleagues (2008) suggest that the BOTMP-SF provides a time effective motor development assessment battery that was validated using a representative sample of American schoolchildren. The test-retest coefficient (r = .84 to .89) is among the best in comparison to other motor performance batteries. The inter-rater reliability of the Total Motor Composite for the BOTMP-SF (r = .92 to .99) is also exceptional. When the BOTMP-SF was developed it was sensitive to theoretical and empirical content assessing a variety of goal-oriented fine and gross motor performance tasks across a large age range (Payne & Isaacs, 2008). However, some minor disadvantages of the BOTMP that have been discussed and include: difficulty obtaining test materials, the open space needed (18 meters) for assessment, and the lack of uniformity between the scoring sheet and subtests assessment protocol (Cools et al., 2008).

PERCEIVED ATHLETIC COMPETENCE

Self-concept can be described as a global assessment to describe “the overall perception of the self.” (Gill, 2000, p. 72) However, beginning in the early 1980’s, researchers in sports psychology began to depart from a global or one-dimensional view of self-concept and began to look at self-concept in terms of individual abilities or attributes. Susan Harter’s Competence Motivation Theory (1981) posited that individuals make self-judgments about various domains of their competence, giving disproportionate importance to specific domains at different points in development. She believed that in young children physical competence, cognitive competence, social acceptance, and behavioral conduct were all examined by one’s self. Then in middle childhood, the evaluated domains evolve to athletic competence, scholastic competence, social acceptance, physical appearance, and behavioral conduct (Harter, 1985). Children and adolescents with strong perceived competence will demonstrate greater motivation to put forth effort and persist in challenging situations or after unsuccessful attempts.

The Self-Perception Profile for children (SPPC) (Harter, 1985) was designed to evaluate self-perception of children in multiple dimensions. The assessment contains five, six-item subscales that evaluates perceived competence in the following dimensions: athletic, scholastic, and social competence, as well as physical appearance and behavioral conduct. The Self-Perception Profile for Children states that the “ athletic competence items primarily refer to one’s ability to do well at sports, including outdoor games, demonstrating one’s athletic prowess.” The perceived athletic competence subscale has been used in recently published studies (Liong, Ridgers, & Barnett, 2015; Morgan et al., 2008) as a marker of a child’s perception of their ability to engage in athletic pursuits and activity with sport-specific motor tasks.

Since perception of physical or athletic competence is present throughout childhood and adolescence, researchers have suggested that clinicians working to increase physical activity in these populations should look to improve perceptions of physical skillfulness and sport competence by encouraging mastery of fundamental motor tasks (Whitehead & Corbin, 1997). When children experience successful performance and mastery of fundamental motor skills they in turn may display improvements in perceived competence (Ulrich, 1987). Further, the mastery of fundamental motor skills may also increase motivation to be physically active due to improvement of self-esteem and enjoyment in participation (Okely, Booth, & Chey, 2004). In addition, participation in organized sport during early to middle childhood is significant because children who develop physical skills in specific activities tend to have a higher perceived competence than those lacking mastery of specific physical skills (Hill, 2009). Success in a particular sport or physical activity is a major reason why children continue to participate, are motivated to be physically active, and set expectations for their future success (Roberts, Kleiber, & Duda, 1981).

Finally, overweight children display lower self-concept in a variety of domains, including academics, sports, and social settings. As previously mentioned, Davison and Birch (2001) saw that girls as young as five years with higher weigh status had lower self-concept. Akin to several other studies (Graf et al.; 2004; Malina et al., 1995; Mond et al., 2007; Okely et al., 2004) Southall and colleagues (2004) found that the actual physical competence of normal weight children, specifically for locomotor tasks, was significantly ($p = .0459$) greater than that of overweight children. However, of note, overweight children also had significantly lower ($p = .0017$) perceived physical competence when compared to their normal weight peers. Therefore, perceived competence of movement abilities cannot be overlooked when creating interventions to treat childhood obesity.

INTER-RELATIONSHIPS AMONG PHYSICAL ACTIVITY, WEIGHT STATUS MOTOR PERFORMANCE, AND PERCEIVED MOTOR COMPETENCE

The Stodden model.

As previously discussed, Stodden and colleagues (2008) provide a detailed schematic (see Figure 3) of several of the developmental mechanisms that may correlate with the physical activity of children and moreover impact the risk of becoming obese and overall health. Since this dissertation focuses on the inter-relationships among physical activity, weight status, motor performance and perceived motor competence included in the Stodden Model, the available literature surrounding the bivariate relationships between the four variables will be considered in the following section of the literature review. The complex interconnectedness among these variables begs the question if one of the bivariate relationships can be independently and accurately studied without considering or controlling for the other two variables. Therefore, papers investigating a joint association's (e.g. weight status and motor performance) relationship to the physical activity levels of children will be discussed.

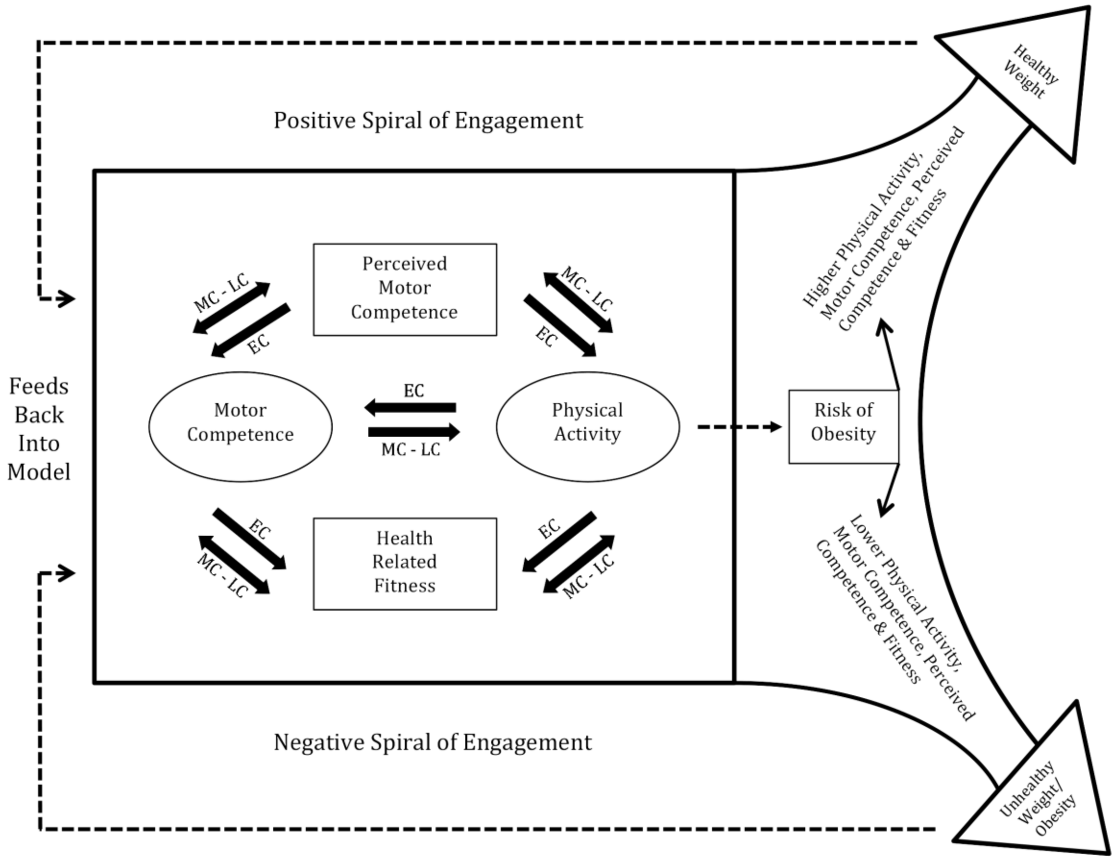

Figure 3. Adapted from Stodden and colleague's (2008) model to explain developmental mechanisms of physical activity levels of children

Relationship between perceived motor competence and motor performance.

A unique relationship exists between perceived motor competence and motor performance. Both independently assess factors in diverse domains, but they also have such an intertwined relationship that makes it difficult measure one without considering the impact of another. Raudsepp & Liblik (2002) found children and adolescents (280 Estonian 10- to 13-year olds) can evaluate their motor performance moderately well ($r = 0.25 - 0.56$, $p<.05$) when compared to measurements of their actual motor performance (aerobic fitness & functional strength). Likewise, 218 American children between 9 and 11 years old (Rudisill, Mahar, & Meaney; 1993) completed assessments of both perceived motor competence and motor performance (combined upper and lower body motor tasks); the correlation between these markers also possessed moderate strength ($r =.48$). When age was considered in the model the correlation strengthened ($r = .51$, $p <.001$). In the Raudsepp & Liblik study (2002), older participants (12- and 13- year olds) typically had more significant correlations ($p<.001$ vs. $p<.01$) when compared to younger counterparts (10- and 11-year olds).

Further, correlations were weak ($r=.20$, $p<.001$) in a sample of Danish children (6- and 7-year-olds) attempting to rate their perceived motor competence in comparison to results on the KTK motor performance battery. When KTK results were compared to parent and teacher evaluations correlations were improved but still weak ($r=.23$ & $r =.31$, $p<.001$), relationships were still very modest for this age range (Toftegaard-stoeckel, Groenfeldt, & Andersen, 2010). Similiarly, Liong, Ridgers, and Barnett (2015) found that Austrailian children's (6- and 7- year-olds) perception of their movement skills compared to actual performance were not significantly related. Boy's perceptions of their movement skills were weakly associated ($r = .26$, $p<.05$) with their actual object control ability, but no other associations were significant. Parents demonstrated a moderate ability to perceive actual object control ability of boys ($r = 0.58$; $p < .05$), actual locomotor ability ($r = 0.48$; $p < .05$) of girls, and overall movement ability ($r = 0.45$; $p < .05$) in the combined sample. These findings are supported by previous research that found a person's ability to accurately evaluate their physical functioning improves with age (Ulrich, 1987); parents and/or teachers also seem to be a valid proxy of a child's movement abilities as well.

Boys had significantly ($p < .01$) higher self-ratings of perceived competence for: sport/athletic competence, strength competence, physical condition competence, and general physical self-worth when compared to girls (Raudsepp & Liblik, 2002). Findings were similar for global perceived competence in Rudisill (1993) study with boys producing a mean score almost 8 points higher girls ($p < .01$). These trends persisted in young subjects as well; boys rated their physical competencies higher (17.3 vs. 15.7; $p < .001$) than girls in the 2010 Toftegaard-Stoeckel study. In a similarly age sample, Liong, Ridgers, and Barnett (2015) found that boys had higher values for perceived total motor and object-control, but girls had a higher mean score for perceived locomotor abilities. However, the only significant difference between boys and girls was for mean perceived object control score (20.6 vs 19.2; $p = .01$).

Overall, these papers suggest that children perceive their motor performance fairly well and older children are more accurate with their appraisals. Boys also tend to have a more robust sense of perceived competence in comparison to girls regardless of age. These findings could explain some the decline in physical activity participation observed throughout adolescence, especially that of girls. Poor perception of one's motor skills could lead to decreased motivation or confidence to participate in recreational and structured physical activities.

Relationship between weight status and motor performance and/or perceived motor competence.

Over the last several years a small cluster of studies have examined the bivariate relationships between both motor performance and perceived motor competence with weight status or body composition. A thorough literature search using various combinations of the keywords “motor skill performance”, “motor competence”, “perceived motor competence”, “weight status”, “adiposity”, “body fat”, etc. yielded nine relevant studies which are considered below.

Okely et al. (2004) assessed the body mass index (BMI) and motor performance abilities of 4,363 children and adolescents in 4^{th}, 6^{th}, 8^{th}, and 10^{th} grades as part of the New Wales Schools Fitness and Physical Activity Survey. Process-oriented assessments of fundamental movement skills such as hopping, kicking, catching, and running were conducted at each grade level. The motor performance quotients of non-overweight participants were significantly greater when compared to overweight participants in all 8 gender-specific grade categories. Further, overweight students were two times more likely to be classified in the lowest quartile of motor performance. In similarly aged (7- to 17-year olds) sample, Malina and colleagues (1995) found a negative association between adiposity (measured by skinfolds) and balance, speed, strength, and power. The variances explained by the % body fat were as follows: speed of limb movement-plate tapping (0% to 3%), balance-flamingo stand (0% to 5%), speed and agility-shuttle run (2% to 12%), static strength-arm pull (4% to 12%), explosive strength-standing long jump/vertical jump (11% to 18%).

The relationship between motor skill performance and weight status (BMI classification) was examined in two studies of younger children. BMI was determined in 668 (341 boys, 327 girls) German 1st graders. Motor skills were assessed with the KTK- motor performance battery. Motor performance quotients demonstrated a weak inverse association with BMI (r = - 0.164, p < .001) in this sample. The associations were low in girls (r = - 0.209, p = 0.001) and boys (r = - 0.165, p = 0.006) in the sex-specific analyses (Graf et al., 2004). In a similar investigation, Mond et al. (2007) assessed selected gross motor skills (balancing on one leg, hopping on one leg, etc.) and BMI in 9,415 Bavarian children (mean = 6.0 years). Children classified as obese by BMI had greater prevalence of impairment in the performance of gross motor skills than children classified as non-obese with a trend toward significance (8.9% vs. 6.2%, p = .08). However, it was observed that boys had a significantly greater prevalence (8.2% vs. 3.6 %, p < .01) of impairment in the performance of gross motor skills than girls in this study.

A 2-year longitudinal analysis of gross motor coordination was conducted on 100 children 6-10 years old. Half of the children were considered normal weight (NW) and the remaining 50 were considered overweight of which 8 were classified as obese (OWOB) by BMI. Motor coordination was assessed using the Körperkoordinationstest für Kinder (KTK) at baseline and the end of the 2-year time frame. A variation of the Flemish Physical Activity Questionnaire (FPAQ) was also used to survey physical activity participation at baseline. Participants were pair-matched by gender and age across the BMI classifications. After matching children by age and gender across the BMI classification, analyses revealed significant differences (p<.001) existed in KTK total motor quotient between groups at both baseline and 2-year follow-up with NW children recording better scores. Normal weight children also showed greater improvement in KTK scores over time when compared to OWOB; thus the gap in motor coordination between NW and OWOB increased significantly over a 2-year period (p = .012). Multiple regression revealed that baseline BMI was responsible for 37.6% of the variance in motor coordination 2 years later (D'Hondt et al., 2013). A larger (n = 954; 500 girls, 454 boys) cross sectional sample of the same population (D'Hondt et al., 2011) was stratified into 3 age groups (5-7 years, 8-9 years, 10-12 years) that were compared by weight status (healthy-weight, overweight, obese). Both overweight and obesity displayed poorer global motor performance scores ($p < 0.001$). Overweight and obese children in the 10-12-year-old group also exhibited significantly poorer motor performance than overweight and obese children 5 to 7 years old ($p < 0.01$). These findings show that weight status and/or body composition can have negative impact on the performance of motor skills, but the variance explained is dependent on the type of motor task assessed. The differences in motor performance between children of normal weight status and those that overweight and/or obese may also strengthen as children age, making remediation even more challenging.

Three studies were identified that discuss the differences in perceived motor competence between normal weight and overweight/obese children. Results from these investigations parallel those of actual motor performance when assessed by weight status. In the first, 116 Australian children complete the Self-Description Questionnaire and BOT-MP. Overweight children ($n = 89$, mean age = 8.75 ± 1.4 years, BMI z-score = 2.22) had a significantly ($p< .0001$) lower mean (46.26) self-concept of physical abilities than normal weight children (54.79; $n = 27$, mean age = 8.25 ± 1.5 years, BMI z-score = 0.03). Likewise, the mean scores of all 5 sub-scales (bilateral coordination, strength, balance, running speed/agility, upper limb coordination) were significantly ($p<.0001$, $p<.0001$, $p<.0001$, $p<.0001$, $p = .012$) lower in the overweight group than the normal weight group (Poulsen et al., 2011). In the second study, a group of Italian middle school students (Morano et al., 2011) was classified by weight status as normal-weight (n=103), overweight (n=86) or obese (n=71). Normal weight students produced significantly greater values for standing long jump as well as significantly faster shuttle run and 20 and 30 meter sprints times compared to overweight and obese students. However, obese students produced greater throwing distance of a 2 kg medicine ball, but the differences were not significant. Normal-weight children scored significantly ($p<.001$) higher across the board when compared to overweight and obese counterparts on several domains of physical self-perception (coordination, sport competence and perceived physical ability). Finally, Jones and colleagues (2010) investigated both actual and perceived motor abilities in a large group ($n = 1414$) of 9- and 11-year old Australian children. Global motor performance scores (combination of throwing, catching, running, galloping, hop scores) were significantly ($p<.01$) better in normal weight children compared overweight children for the 9-year old boys, as well as the 11-year old boys and girls, but not the 9-year old girls ($p=.14$). Perceived physical competence showed no difference between either 9-year old gender, but there were significantly better scores for normal weight, 11-year old boys and girls ($p<.001$ and $p = .02$, respectively) compared to overweight group. Akin to the motor performance differences observed between normal and overweight/obese children, perceived motor competence too show seems to display discrepancies by weight status. The divergence looks to increase as children age as well.

In conclusion, weight status tends to be associated with antagonistic effects in both perceived and actual motor performance. The previously discussed studies demonstrate that motor performance and perceived motor competence have a negative association with body mass index and that adiposity can explain modest variance in various strength, agility, and other motor tasks. Poor motor ability and low perception of physical ability may impact a child's psychological outlook and both current and future participation in leisure physical activity and recreational sports. Not participating in organized sport has been seen to further impact future motor performance and physical activity (D'Hondt et al., 2013). The differences in both actual and perceived motor competence across weight statuses may be one specific reason for the steep decline in physical activity frequently observed during adolescence (Eaton et al., 2012)

Relationship between weight status and physical activity. Given the prevalence of both physical inactivity and obesity in U.S. children, it should not be surprising that obese and overweight children tend to be less physically active than their normal weight peers (Belcher et al., 2010; Gordon-Larsen et al., 2000; Must & Tybor, 2005; Sallis et al., 2000). In a systematic review of 20 longitudinal studies of body composition and physical activity or sedentary behavior, Must and Tybor (2005) concluded that physical activity has an inverse association with various markers of body composition (body mass index, % body fat, etc.), which have a direct association with inactivity. The authors further implied that physical activity or minimized sedentary behavior during childhood is protective against development of excessive adiposity during the development years.

When objectively measuring physical activity of preschool children through accelerometery Trost and colleagues (2003) observed significantly lower participation levels and bouts of moderate to vigorous physical activity (MVPA) in overweight boys compared to their normal weight peers. The significant difference were not observed in females; however, the lack of difference in the girls was explained by a generally low level of physical activity that made it difficult to recognize any negative influence weight status may have contributed. In a similar study of 6^{th} grade children (Trost et al., 2001), it was determined that obese students performed significantly less physical activity, both total and bouts of MVPA than non-obese children. However, data analysis was not gender-specific. The physical activity data from NHANES 2003-2004 & 2005-2006 (Belcher et al., 2010) showed that normal weight children recorded significantly ($p<.05$) more counts per minute than overweight and obese children when all ethnicities and ages were assessed together. These findings were the same when assessing genders individually or combined. The deficits in physical activity of overweight and obese children in comparison to their normal weight peers may have been a contributing factor to their differing weight status and could help sustain observed disparities in health.

Relationship between motor performance and physical activity. Ten studies were identified that have examined the association between physical activity and motor performance of children. Eight of the ten studies utilized cross-sectional data and two conducted investigations with longitudinal information.

Results of the two longitudinal studies are in contrast and it is not definitive whether or not childhood motor performance is a discrete predictor of adolescent physical activity. McKenzie and colleagues (2002) tested the motor performance of 207 Mexican American and Anglo American children at 4, 5, and 6 years of age. Motor skill performance included measures of lateral jumping to evaluate agility and locomotion, catching a ball to evaluate hand-eye coordination, and balancing on one foot to evaluate balancing in each of the participants. Habitual physical activity was estimated by averaging the results of two 7-day physical activity recalls, an instrument validated in this age group, that were administered by trained assessors at both 11 and 12 years of age. The results indicated that motor performance between the ages of 4-6 years of age was not a significant predictor of physical activity between the ages of 11 and 12 years of age in this sample of children. However, evidence from another longitudinal study (Barnett et al., 2009a) suggested that childhood object control proficiency (kicking, catching, and throwing) was a significant predictor of adolescent physical activity in 481Austrailians. Childhood object control proficiency explained significant variance in both time spent in moderate-to-vigorous intensity physical activity (12.7%, p = .001) and organized activity (18.2%, p =.003) during adolescence. These differences could be explained by the motor performance assessment instruments that we used in the two studies, as well as the ages at which motor performance was assessed. Barnett and colleagues (2009a) used a validated instrument (New South Wales Department of Education and Training, 2000) that included component analysis of a twelve motor tasks to assess global motor performance. Subjects in this study were at a minimum development age (7.9 years) that motor development abilities have begun stabilizing and approach the mature state (Scammon, 1930; Gutteridge, 1939). However, McKenzie and colleagues (2002) reported to have chosen three independent motor tasks that were fundamental in nature and could be easily assessed in the home environment; this assessment procedure was not representative of global motor abilities nor had it been validated. Further, the ages of the subjects in this study (4-6 years) are associated with a period of substantial variance and individualized progress toward the mature state of motor tasks (Clark & Whitall, 1989; Gutteridge, 1939). Therefore, until motor performance has reached the mature state, which depending on the motor skill is approximately 8 years of age, it could be difficult to use for prediction of future physical activity.

Five cross-sectional studies (Graf et al., 2004; Fisher et al., 2004; Raudsepp & Päll, 2006; Williams et al., 2008; Wrotniak et al., 2006) assessed the associations between various indicators of motor performance and physical activity in developing children. Correlation coefficients ranged from weak (r = .10) (Fisher et al., 2004) to moderate (r = .55) (Raudsepp & Päll, 2006). Fisher et al. (2004) examined the fundamental movement skills and habitual physical activity levels of 394 Scottish preschoolers (mean age of 4.2 years). Fundamental movement skills were assessed using the Movement Assessment Battery for Children. Physical activity was assessed using the MTI accelerometer for 6 days. Less than 1100 counts per minute (cpm) was considered sedentary behavior, while 1100-3200 cpm and > 3200 cpm were considered light-intensity and MVPA, respectively. No differences in physical activity or skill ability existed between boys and girls, so results were presented with all participants pooled. Both total physical activity and percent time spent in MVPA were weakly correlated with total movement skills score ($r = .10$, $p = .039$; $r = .18$, $p < .001$). In 2006, Wrotniak and colleagues reported on 65 American children who completed the Bruininks-Oseretsky Test of Motor Proficiency Short Form and were assessed for habitual physical activity using accelerometry. Less than 800 cpm was considered sedentary behavior, while 800-3200 cpm and > 3200 cpm were considered light-intensity and MVPA, respectively. Correlations identified that motor proficiency had a protective effect in that it had a negative association with sedentary behaviors ($r = -0.31$, $p = 0.012$) and had positive association with moderate intensity activity ($r = 0.33$, $p = 0.008$). Both associations were moderate. The study by Raudsepp & Päll (2006) produced the highest correlations between physical activity and motor performance. Motor performance was assessed by kinematic video analysis of the standing long jump and the overhand throw, and physical activity was assessed by both a Modified Children's Physical Activity Form (MCPAF) and accelerometer in 133 Estonian children (mean age of 7.6 years). Developmental levels of both skills were moderately correlated to outside school skill-specific physical activity assessed by the MCPAF ($r = 0.44$ (throw), 0.55 (jump)). However, developmental skill level was not correlated with overall level of physical activity from the accelerometer data.

Further, an investigation by Graf et al. (2004) highlighted in the previous section examined motor skill performance and leisure behavior participations. Motor skills were assessed with the KTK- motor performance battery in 668 German 1st graders. Leisure behavior was classified by parental questionnaire information as no sport, irregular sport, regular sport, club sport, or club sport and regular sport. Results of ANCOVA indicated a significant ($p = .035$) graded relationship across the five leisure behavior groups with children in the highest activity quintile demonstrating the highest KTK- motor performance quotient score. Similarly, Williams et al. (2008) identified low to moderate associations between both locomotor and object control skills and percent of time spent in MVPA in 118 4-year-olds; correlations were $r =.31$ and $r =.26$, respectively. Correlations were slightly higher when percent of time spent in vigorous physical activity was partitioned out; correlations were moderate at $r =.37$ and $r =.32$, respectively. Further, when comparing children by their total motor skill performance scores, children in the highest performance tertile had the lowest percent of time spent in sedentary activity, as well significantly greater percent of time spent in MVPA and VPA compared to children in the lowest performance tertile, 13.4% vs. 11.4%, $p<.05$; 5.0% vs 3.8%, $p<.01$.

Assessing the relationship between motor skill performance and physical activity in adolescent populations has provided evidence that the relationship may lose strength as individuals age. However, the object control skills of adolescents may be more significant factor impacting physical activity participation levels during this period of life. Okely and colleagues (2001) found significant differences in minutes of organized physical activity between movement skill quintiles in adolescents. Although, mean physical activity levels of each of the 5 motor performance groups were not provided in the paper, the researchers determined that movement skills accounted for 3% of the variance in organized physical activity. Barnett and colleagues (2011) assessed physical activity participation in relation to both locomotor and object control motor skill performance in 215 adolescents (16.4 years). The correlation between physical activity and locomotor skill performance in this sample was significant, but weak ($r = .14$, $p < .05$), explaining only 1.9% of the variance in minutes of MVPA participation per week. However, a moderate correlation ($r = .35$, $p < .01$) was observed between object control skill performance and weekly MVPA participation, explaining 12.3% of the variance. These findings emphasize that the motor performance abilities can lead to greater physical activity participation, but also that greater physical activity participation can lead to stronger motor performance abilities.

When specifically addressing the bivariate relationship in a sample classified as obese, Morgan and colleagues (2008) found that motor skill proficiency was significantly correlated (correlations ranged from 0.24 to 0.53) with moderate physical activity (MPA), vigorous physical activity (VPA), and mean counts per minute (CPM) in 137 Australian children. However, only %MPA and %VPA were significantly correlated with motor performance in obese girls. Regression analysis identified that object-control proficiency explained 25% of the variance in CPM, 31.3% of %MPA, and 11.5 % of %VPA in boys.

In summary, children displaying the highest motor performance in a specific sample generally are observed to have the highest physical activity levels. Motor performance abilities have been found to explain some of the variance in physical activity levels of children; especially the ability to perform object control skills. The amount of variance in physical activity explained by motor performance could be dependent on the instrumentation selected to assess motor performance and physical activity, as well as the age of subjects at assessment.

Relationship between perceived motor competence and physical activity.

Historically, children participating in sport were seen to have greater levels of perceived motor competence compared children who do not participate. Roberts and colleagues (1981) assessed perceived competence (PSPP) and sport participation in 143 fourth and fifth graders. Children participating in sport possessed significantly ($p<.05$) higher scores for perceived physical competence than nonparticipants. Results also revealed that participants in organized sports were more persistent and had higher expectations of future success. These results are consistent with previous declarations that perceived competence in physical skills has an integral relationship to participation in and motivation toward physical activity during childhood (Harter, 1981).

Researchers have recently begun to re-examine the relationship between perceived motor competence and physical activity more frequently, specifically addressing the predictive ability of physical self-perception. A 2000 study reported the physical activity levels of 466 Canadian school children 10-14 years old using a 7-day recall. Self-perceptions of physical conditioning, sports competence, strength, body appearance and general physical self-worth were measured by the PSPP. Various structural models were run for the relationship between these measures; physical self-perception accounted for 27 to 29% of physical activity in the sample. Perception of physical conditioning and sport skills had moderate correlations ($r = .46$ to .48) to physical activity (Crocker, Eklund,& Kowalski, 2000). Using longitudinal data, Davisson, Downs, and Birch (2006) observed a low to moderate correlation ($r= .27$, $p < .05$) between perceived motor competence at 9 years of age and physical activity at 11 years of age in 174 girls. However, only 7.3% of the variance of physical activity would be explained in this longitudinal sample. Finally, Barnett and colleagues (2011) assessed physical activity participation in relation to perceived sports competence in 215 adolescents (16.4 years) . The correlation between physical activity and perceived sports competence in this sample was moderate ($r =.31$, $p<.01$), explaining 9.6 % of the variance in minutes of MVPA participation per week.

Just as motor performance abilities are an important target when attempting to increase physical activity levels of children and adolescents, the perception of one's ability to perform said skills cannot be overlooked. The reciprocal relationship between perception of and actual motor performance has been highlighted and should be considered when designing intervention models. Due to the recognizably lower perceived motor competence scores, specific attention should be given to improving these self-assessments in overweight and obese children.

Physical activity intervention programs targeting improvements in motor skill performance and increased perceived motor or athletic competence in normal weight and overweight/obese children. A recent review paper (Morgan et al., 2013) identified 19 intervention programs seeking to improve one or more fundamental motor skills in children ranging in age from 5 to 18 years of age. Six intervention programs (Boyle-Holmes et al., 2010; Cliff et al., 2007; Foweather et al., 2008; McKenzie et al., 1998; Salmon et al., 2008; van Beurden et al., 2003) discussed in the review included both boys and girls within a similar age range (8 to 12) to the analytic sample of this dissertation study. An additional program (Morano et al., 2014) was identified that used a multi-component program that sought to encourage a physically active lifestyle through improvements in motor performance, as well as perceived motor competence.

In general, results from these seven programs (Boyle-Holmes et al., 2010; Cliff et al., 2007; Foweather et al., 2008; Morano et al., 2014; McKenzie et al., 1998; Salmon et al., 2008; van Beurden et al., 2003) indicated that improvements in motor skill performance are possible in children 8 to 12 years old who participate in intervention programs compared to controls. Pre- to post-intervention improvements were similar between short-term programs (9 to10 weeks) (Cliff et al., 2007; Foweather et al., 2008) and long-term programs (6 months to 2 years) (Boyle-

Holmes et al., 2010; Morano et al., 2014; McKenzie et al., 1998; Salmon et al., 2008; van Beurden et al., 2003).

Specifically, a school-based program of moderate duration (~6 months) was undertaken with a large sample (n= 1045) of children (7 to 10 years) (van Beurden et al., 2003). Participants in the intervention group attended schools in which a "buddy" (pre-service physical education teacher) implemented physical education lessons focused on increasing physical activity and improving fundamental motor skills throughout the school day. The intervention group showed improvements in every skill ranging from 7.2% (girls throw) to 25.7% (boys sprint). Improvements in MVPA and VPA increased 4.5 and 3.0%, respectively, were not statistically significant. In terms of long-term follow-up, the effects of the intervention were insignificant six-years later (Barnett et al., 2009b) with the exception of an advantage in catching ability. In comparison the 21-month Children's Health InterventionaL Trial (CHILT) project (Graf et al; 2008) found significant increases were apparent in lateral jumping and balancing backwards ($p = .005$, $p = .007$, respectively) for children in intervention schools compared to those in the control at four years post-intervention. However, the baseline measurement for the CHILT intervention was conducted when participants were 6 to 7 years old.

Two identified intervention programs specifically targeted overweight and obese children and adolescents. Cliff and colleagues (2007) assessed the feasibility of SHARK, a community-based physical activity motor development program. Thirteen overweight and obese children (10.4 years ± 1.2 years) participated in the 10-week, pilot program. Pre to post-program improvements were observed in both gross motor quotient of the TGMD-2 motor battery ($p<.001$) and perceived athletic competence assessed by the subscale of the Self-Perception Profile for Children (SPPC) ($p = .025$). Though declines were evident, significant improvements compared to baseline were still apparent at 9-month follow-up. The SHARK program did not demonstrate the ability to reduce BMI or improve physical activity participation. In fact, there was a significant decline in minutes of MVPA from baseline to post-program ($p = .001$) and again form post-program to follow-up ($p<.001$). Using a similarly aged sample, an outpatient clinical program in Italy assessed forty-one child (9.2 ± 1.2 years) participants before and after an 8-month, 80 session physical training program (Morano et al., 2014). The program targeted in improvements in both actual and perceived motor competence in attempts to help participants attain an active lifestyle. Post assessment revealed significant reduction in body mass index ($p =.004$), but no apparent improvement in percent body fat. Significant increases ($p<.001$) were also observed in self-reported physical activity, gross motor quotient of the TGMD motor battery, and perceived physical abilities assessed by the Perceived Physical Ability Scale for Children.

Findings from the above physical activity intervention programs indicate that perceived motor or athletic competence and motor performance abilities can be improved. The greatest improvements were typically associated with programs of longer duration and those working specifically with overweight and obese children. This trend makes sense as overweight and obese children tend to have deficient motor performance abilities and perceived competence in comparison to their normal weight peers, which would allow for greater potential for improvement. Due to limited follow-up data and ambiguous findings, it is unclear whether the pre- to post-program improvements in motor performance abilities and perceived athletic competence can be sustained.

The relationships between perceived motor or athletic competence and physical activity, as well motor performance and physical activity are evident in the literature. However, only one of the intervention programs previously discussed showed an increase in physical activity when targeting improvements in motor performance and perceived athletic competence. Further investigation into the long-term impact these intervention programs have on physical activity participation and associated reduction in obesity prevalence is warranted.

SUMMARY AND CONCLUSION

In summary, the prevalence of childhood overweight and obesity has risen to epidemic levels with some stabilization in recent years. Overweight and obese children are at higher risk for several health-related disorders such as hypertension and cardiovascular disease, participate in less physical activity, and have lower motor performance abilities and perceived athletic competence compared to normal weight peers. The bivariate relationships between physical activity and associated correlates have been established in the literature previously. However, analyzing the interaction between perceived athletic competence and motor performance to predict physical activity participation has not conducted in a representative sample.

The research from this dissertation could provide substantial evidence for the necessity of developing sufficient motor performance and resilient perceived athletic competence in the promotion of childhood physical activity. This research will identify the impact of weight status on physical activity patterns of children and identify if there are distinct differences in participation levels for children with low versus high motor performance abilities or weak versus strong perceptions of motor competence. Further, this dissertation could establish if greater emphasis should be put on physical education and other opportunities for motor skill development and/or supporting enhancement of perceived athletic competence, which could be important practices in attempting to increase the physical activity levels of young children. In particular, these findings could assist in development of strategies within multi-disciplinary intervention programs that aspire to promote greater physical activity participation in overweight and obese children.

Finally, the techniques to assess physical activity, body composition, motor performance, and perceived athletic competence vary greatly in quality and sophistication within previous studies. Therefore, this dissertation seeks to implement dependable, conventional assessment and statistical techniques. Overall, this dissertation seeks to provide a better understanding of the interrelationships among physical activity, weight status, motor performance, and perceived athletic competence using a representative sample of children.

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CHAPTER 3: ASSOCIATIONS OF BODY MASS INDEX, MOTOR PERFORMANCE AND PERCEIVED ATHLETIC COMPETENCE WITH PHYSICAL ACTIVITY IN NORMAL WEIGHTAND OVERWEIGHT CHILDREN

INTRODUCTION

Childhood obesity is recognized as one of the top public health issues in North America (McLanahan et al., 2006; Public Health Agency of Canada, 2011). The prevalence of overweight and obesity among children and adolescents in the United States (U.S.) and Canada is approximately 32%. Although obesity is recognized as a complex multi-factorial condition (Eisenmann, 2006), physical inactivity has been identified as a significant factor in the development of obesity (Must & Tybor, 2005).

In general, overweight and obese children and adolescents have been shown to display lower physical activity levels (Belcher et al., 2010; Colley et al., 2011), poorer motor performance (i.e. motor competence, motor ability, fundamental movement skills) (Malina et al., 1995; Graf et al., 2004; Okely et al., 2004, Mond et al., 2007; Jones et al., 2010; Morano et al., 2011; Poulsen et al., 2011; Southall, Okely, & Steele, 2004) and lower perceived motor competence (self-perception of ability to perform motor skills) (Jones et al., 2010; Poulsen et al., 2011; Southall, Okely, & Steele, 2004) when compared to their normal weight peers. In turn, motor performance (Okely et al., 2001; Graf et al., 2004; Fisher et al., 2004; Reed et al., 2004; Raudsepp & Päll, 2006; Wrotniak et al., 2006; Morgan et al., 2008; Williams et al, 2008; Barnett et al., 2009) and perceived motor or athletic competence (Roberts, Kleiber, & Duda, 1981; Crocker, Eklund, & Kowalski, 2000; Davison, Downs, & Birch, 2006) explains between 5 to 30% of the variance in physical activity. In addition to each correlate individually explaining a portion of the total variance in physical activity, motor performance and perceived motor competence are also synergistically related to physical activity (Toftegaard-stoeckel, Groenfeldt, & Andersen, 2010; Liong, Ridgers, and Barnett, 2015). More specifically, motor performance and perceived motor competence are moderately correlated with each other and also provide an additive effect on the explained variance in physical activity participation. These findings suggest that motor performance abilities and perceived motor competence could be important factors to address when attempting to increase the physical activity levels of children, especially in those who are overweight or obese.

Stodden and colleagues (2008) have proposed a model that posits that the risk of becoming overweight and obese is based on the interrelationships amongst physical activity, perceived motor competence, motor competence (motor performance), and health-related fitness. In addition, the model further suggests that if a child is overweight/obese that they may display poor motor performance and low perceived motor competence that could lead to further decline in physical activity participation. According to Stodden and colleagues, those who possess higher perceived motor competence during early childhood will tend to develop better motor competence. Hence, these children will be more likely to persist when attempting a new task until mastery than a child with inadequate perceived motor competence. As previously noted, children with greater perceived motor competence are also seen to possess greater levels of physical activity. Most notable in early childhood, motor competence is seen to be greater in children with increased opportunities for participation in physical education, recreational sport, and other physical activity (Fisher et al., 2005). In addition, the Stodden model suggests that as a child approaches middle childhood and adolescence, poor motor competence negatively impacts perceived motor competence. Older children and/or adolescents that have not established a "strong motor repertoire" may lack the skill(s) and confidence to participate in physical activity. The model suggests that the relationship between perceived and actual motor competence strengthens as a child ages, as does the relationship between motor competence and physical activity. The model ultimately predicts weight status (e.g., healthy weight or unhealthy weight/obesity). However, one specific interest is how the healthy weight outcome is shown to produce a "positive spiral of engagement" in physical activity, which includes children with greater motor competence, higher perceived motor competence and higher physical activity levels. The model further suggests that unhealthy weight or obesity may be the result of a "perfect storm" of poor perceived motor competence, low motor competence, and low physical activity levels. When a child is of an unhealthy weight or obese, he or she is more likely to disengage in physical activity, which could further exacerbate their weight problem.

As outlined above, several studies have examined the bivariate correlations between physical activity, body mass index (BMI) or weight status, perceived athletic competence, and motor performance; however, there is a need for a multiple regression analysis that examines these variables simultaneously due to their unique synergistic relationship. In particular, due to the inter-relationships among motor performance, perceived athletic competence, and physical activity, it is of interest to investigate how the combined influence of motor skills and perceived athletic competence can impact physical activity levels during childhood. The use of multivariate analysis has two major advantages: 1) the relative effect of each variable is assessed while others are held constant, 2) the strength of individual variables ability to predict the outcome (physical activity participation) can be compared and the strongest predictors might be targeted for intervention.

The purpose of this study is two-fold: 1) examine the relative influence of age, BMI, motor performance, perceived athletic competence, and SES on physical activity participation in children; 2) examine the interactions among BMI, motor performance and perceived athletic competence on physical activity participation in children

RESEARCH DESIGN AND METHODS

Participants. The Physical Health Activity Study Team (PHAST) project began during the 2004-2005 school year in the Niagara region of Southern Ontario. Ninety-two schools were contacted to recruit children enrolled in 4th grade for participation in the study. Seventy-five (83.3%) of the 92 schools granted permission. Informational and consent forms were sent home from school with students. Informed consent was obtained from 2278 (95.8%) of 2378 fourth grade children enrolled in these schools. All study participants gave verbal assent and had a completed consent form signed by parent or guardian on file with the primary investigator before data collection began. Training and testing protocols were established during the fall of 2004 and the initial wave of data collection occurred in the spring (April and May) of 2005.

Data collected on 2190 children (1104 males; 1086 females) in the 4th grade (ages 8 to 11 years old) during the spring of 2005 were included in this analysis. Of the 2190 participants assessed in the PHAST spring 2005 cohort, 1881 children (955 males; 926 females) had values recorded for age, height, weight, motor performance testing, perceived athletic competence, physical activity, and socioeconomic status. Participants were included in the current analyses only if they had complete data for all of the above variables. There were 213 participants with missing motor performance values, which was the largest missing variable amongst the measures. Comparisons between participants with complete and missing data are shown in Table 2. There were no statistically significant differences in age, body size, physical activity or household income; however, perceived athletic competence score (18.5 ± 4.1 v 17.9 ± 4.1; $p=.024$) and the motor performance percentile (66.9 ± 30.0 v 52.5 ± 33.6; $p<.001$) were significantly higher in those with complete data compared to those with incomplete data.

Measurement of outcome variable: habitual physical activity. The Physical Activity Participation Questionnaire (PAQ) is a 63-item self-report questionnaire that seeks to assess the participation levels of children in free-time play, intramural school sports, community and club sports teams, as well as all other organized physical activities (PA) recalled from the previous year. Higher PAQ scores indicate a greater number of "activity units". The total score ranges from 0-45 with a free-play index from 0 to 16 and an organized-activities index from 0 to 29. Free-play is assessed by recalling typical activity choices and organized activities catalog participation in organized athletic and competitive activities over the previous year.

Two-week test-retest reliability of the PAQ among children in primary grades four through six was been found to be r = 0.81 (Hay, 1992). The PAQ has also has shown moderate correlation (r = 0.62) to teacher evaluation of activity participation; however, it has not been validated against an objective measure of physical activity (e.g., accelerometer). Further, the instrument has good construct validity with expected differences between genders and between individuals living in different geographic locations (urban vs. rural) (Hay, 1992). For this study, the PAQ was administered in a classroom setting with a brief description of instructions by research assistants, who were available to answer questions and provide assistance when needed.

Assessment of physical activity correlates.

Age. Chronological age (yrs) was calculated as the decimal age (observation date minus birthdate).

Anthropometry. Height and weight were measured according to standard procedures. Height was measured to the nearest 0.2 cm using a portable stadiometer (SECA, Hamburg, Germany) without the child wearing shoes. Children stood vertically erect with heels together, eyes forward, shoulders relaxed and arms at their sides. Weight was measured to the nearest 0.1 kg using a calibrated electronic scale (Tanita, Tokyo, Japan). Children wore athletic shorts and t-shirt, which was standard for their physical education classes. These testing sessions occurred in a private testing area at prescheduled times.

The BMI was calculated using the following equation: body weight in kg/height in m^2. Age- and gender- specific BMI cut points (Kuczmarski et al., 2002) were used to determine classification of BMI percentiles into one of two groups: normal weight (NW)- $<85^{th}$ percentile or overweight/obese (OW/OB)- $\geq 85^{th}$ percentile. Participants with weight status classified as underweight ($<5^{th}$ age- and gender- specific percentile) were included in the normal weight group. This decision was made because there were only 12 males and 22 females classified as underweight, and more importantly there were no significant differences (other than body mass index) when comparing gender-specific mean values on all variables by weight status ($<5^{th}$ percentile versus $\geq 5^{th}$ percentile).

Motor performance. Motor performance was assessed using the short form of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP-SF) (Bruininks, 1978). The BOTMP-SF is a well-known and well-accepted (Cool et al., 2008; Payne & Isaacs, 2008) product-oriented test used to assess fine and gross motor skills for children between the ages of 4 and 21 years. The short form of the test has shown strong validity (r = .90-.91) when compared against the long form in children ages 8 to 14 (Bruininks, 1978). The BOTMP-SF consists of 14 items from all 8 subtests of the complete form which include: standing on the preferred leg on balance beam, walking heel/toe on a balance beam, tapping feet while making circle with fingers, jumping up and clapping hands, standing broad jump, catching a tossed ball with both hands, throwing a ball at a target with the preferred hand, running speed and agility (shuttle run), response speed, drawing a line through a straight path with preferred hand, copying a circle with preferred hand, copying overlapping pencils with the preferred hand, sorting shape cards with preferred hand, and making dots in circles with preferred hand. The raw scores from each of the 8 subtests are converted to a scale score which then can be used to establish a percentile rank (i.e., 77^{th} percentile) or a standard score ranging from 24-75 for each subtest by age group in 6-month intervals from 4.6 to 14.5 years of age. The percentile rank of each participant was used as the measure of motor performance for the analyses within this study.

Prior to conducting motor performance evaluations in the PHAST study, a subset of the research assistants were trained by a motor developmentalist experienced in conducting the BOTMP-SF protocol. The motor testing of PHAST study participants was completed one child at a time. However, due to conducting assessments in 75 different schools, the testing environment varied. The setting that was selected at each school was chosen to allow open space, minimize distraction and maximize privacy.

In an attempt to validate the BOTMP testing in this study, 24 children were reassessed by a pediatric occupational therapist, the testing procedures and findings were supported by the clinician. Two years after initial assessment, 77 children were also selected from a randomly selected subset of schools in the PHAST. These participants results were retested by different examiners blind to the original BOTMP-SF results; the correlation between the two sets of scores was 0.70 ($p < 0.001$). This demonstrated that the relative percentile rank of children tracked moderately well.

Perceived athletic competence. The Self-Perception Profile for children (SPPC) (Harter, 1985) was designed to evaluate self-perception of children in multiple dimensions. The assessment contains five, six-item subscales that evaluates perceived competence in the following dimensions: athletic, scholastic, and social competence, as well as physical appearance and behavioral conduct. The scoring system utilizes a 4-point scale in which the participant must first decide which of two statements best describes them and then indicate whether the statement is 'sort of true' or 'really true' for them. Each item can be scored from 1 (low self-perception) to 4 (high self-perception). Both the total subscale and average subscale scores can be reported.

The Self-Perception Profile for Children states that the " athletic competence items primarily refer to one's ability to do well at sports, including outdoor games, demonstrating one's athletic prowess." The perceived athletic competence subscale relates most closely to performance of motor skills and their application to sport participation. Therefore, since a true measure of perceived motor competence was not utilized in the PHAST study, the perceived athletic competence (PAC) total subscale score was used in this analysis. It possesses test-retest reliabilities that range from r = .76 to .91 depending on the sample.

Socioeconomic status. In this study, neighborhood income was used as a marker of SES. SES is often measured using level of parental education, parental occupation or household income. We chose to focus on income because in this context, we are specifically interested in the ability to pay for access and participation in organized sport and recreational programs. Certainly, previous research has shown that participation in organized sport and physical activity is lower in low-income as compared to high-income neighborhoods (Kamphuis et al., 2008). Moreover, White and McTeer (2012) found household income to be the strongest predictor of children's participation in organized sport.

In this study, instead of parent reported income or occupation, the reported residential postal code of each child was recorded. The postal codes were then used to generate proxy estimates for household income based on census information. Postal codes were geocoded in Arcmap using the North America Geocode Service from Esri. Mean household income data was obtained from the 2006 census of Canada according to the dissemination area (one or more blocks with a population between 400 to 700 people) associated with the postal code reported. Neighborhood income has been shown as a valid proxy for household income in population studies, especially in relation to health-related outcomes (Mustard, Derksen, Berthelot, & Wolfson, 1999).

Statistical analysis.

Descriptive statistics were calculated for all variables. To examine the relationship amongst variables a Pearson correlation matrix was created for each gender. Further, a forced regression analysis (main effects model) was conducted to identify the percent variance in habitual physical activity participation explained by the following variables: BMI, motor performance and perceived athletic competence. To control for the effect of socioeconomic status and decimal age, these variables were placed in separate blocks of independent variables within the regression model. Based on % variance explained in bivariate relationships discussed from previous literature it was hypothesized that each of the potential correlates would each explain greater than 5 % of the variance in physical activity, with the complete model explaining 20% of variance. Variance inflation factors (VIFs) were calculated to assess for multi-collinearity between the independent variables in the final model. Variance inflation factors between independent variables less than 10.0 are considered to be free of multi-collinearity.

A three-way interaction term (BMI x motor performance x perceived athletic competence) was computed as were all lower-level two-way interaction terms. The main effects, two-way and three-way variables were force entered into a multiple regression equation (interactions model) to identify the percent variance in physical activity. To control for the variance of socioeconomic status and chronological age, these variables were placed in a separate block of independent variables within the regression model. Variance inflation factors were calculated to assess for multi-collinearity between the independent variables (main effects, 2-way interaction terms, and 3-way term) in the final model.

The likelihood of multi-collinearity being present in an interactions model is very high due to the fact that each independent variable is entered into the regression analysis multiple times (main effect, 2-way interactions, and 3-way interaction). Therefore, in an attempt to reduce the likelihood of multi-collinearity being present between variables; the technique of centering was implemented. Centering of the independent variables included in the 3-way interaction was conducted by subtracting each subject's score from the gender-specific mean value of the variable. After this process, the interactions model was rerun and VIFs were checked again.

All analyses were conducted using Statistical Package for the Social Sciences (SPSS) Version 19.0. Significant differences will be determined by a p-value less than .05.

RESULTS

Descriptive statistics for the total sample and by gender are presented in Table 3. Although age, height, weight and BMI were similar between genders, boys had significantly higher mean BMI percentile (63.6 ± 27.4) when compared to girls (60.6 ± 29.6). Less than 2% of all participants were classified as underweight, 68% were normal weight (NW), 15.8% were overweight and 14.4% obese, and these percentages were similar between genders. There were no significant differences in PA participation between genders. Girls had significantly lower PAC (17.8 ± 4.3 vs. 19.1 ± 3.9, p = <.001) and MP (62.6 ± 30.4 vs. 71.2 ± 29.00, p <.001) than boys.

Pearson correlation coefficients amongst variables are reported in Table 4 for boys and girls. In boys, PA participation was significantly (p<.001) correlated with PAC, MP, and SES but not with BMI. Correlation coefficients were low between PA participation and both MP (.191) and SES (.116), but there was a moderate relationship (.413) between PAC and PA. Other significant (p<.001) correlations were shown between PAC and MP (.267), and BMI and MP (-.316). In girls, PA participation was significantly correlated with PAC, MP, BMI and SES. Correlation coefficients were low between PA and MP (.185; p<.001), BMI (-.071; p<.05) and SES (.050; p<.01), but PAC was moderately correlated with PA (.420; p<.001). Other significant, but weak correlations were found between PAC and MP (.224; p<.001), as well as BMI and motor performance (-.237; p<.001).

Results of the linear regression analysis with forced entry (main effects model) for physical activity participation in boys and girls are presented in Table 5. For boys, 18.3% of the variance in habitual physical activity participation was explained by BMI, MP and PAC. When socioeconomic status was included in the model, the total variance explained was 18.8%. When using a stepwise approach, PAC independently explained 17% of the variance, while MP, BMI, and SES only accounted for 0.6%, 0.7%, and 0.5% of the total variance, respectively. Chronological age was not a significant predictor of physical activity participation. Similar to boys, PAC was also the most robust predictor of physical activity participation in girls explaining 17.5% of the variance. MP contributed an additional 0.8%. BMI, SES, and chronological age were not statistically significant correlates of physical activity participation in girls. All VIFs in the main effects models ranged from 1 to 1.2 demonstrating that multi-collinearity was not present between correlates.

All main effects, two-way interactions and three-way interaction term were examined in the forced multiple regression analysis (interactions model) for physical activity participation in boys and girls. When the main effects and interaction terms were uncentered there were no significant findings and VIFs ranged from 50 to 781, which indicates multi-collinearity was present. In an attempt to reduce multi-collinearity and reduce VIFs, all main effects were centered. The two-way and three-way interaction terms were recalculated using centered main effects and the model was rerun. For boys, the percent variance in habitual physical activity participation explained by the 3-way interactions model was 18.3%. However, the only predictors with significant beta values were the centered values for BMI, MP and PAC, which was what the main effects model demonstrated. For girls, the centered multiple regression model explained 18.1%, but the only predictors with significant beta values were the centered values for MP and PAC. None of the 2-way interactions terms or the 3-way interaction were statistically significant.

DISCUSSION

This study examined the relative influence of age, BMI, MP, PAC, and SES, and their interactions on physical activity participation in a large sample of children. The main finding was that PAC explained approximately 17% of the total variance of participation in physical activity. The interaction models produced no significant results.

The prevalence of overweight (15.8%) for boys and girls was slightly lower than those reported in a nationally representative sample of 5-11 year old Canadian boys (19.8%) and girls (19.6%)(Roberts et al., 2012). Further, significant differences exist in obesity prevalence between boys (19.5%) and girls (6.3%) in Canadian national data (Roberts et al., 2012); however, were not present in the current study as both genders had an obesity prevalence of 14.5%. The MP centiles for boys (71^{st}) and girls (63^{rd}) in the current study are both classified at the upper end of the “average” classification (18^{th} to 83^{rd} centiles) for age-specific normative data (Bruininks & Bruininks, 2005). The differences in MP between girls and boys observed here confirm the well-known finding that boys possess greater MP abilities than girls (Thomas & French, 1987). The PAC values in the current study are similar to those found in similarly aged children (Muris, Meesters, & Fijen, 2003; Harter, 2012; Raudsepp & Liblik, 2002; Seabra et al., 2013). Significant differences in PAC between girls and boys observed here also confirm previous reports (Harter, 2012; Raudsepp & Liblik, 2002; Toftegaard-stoeckel, Groenfeldt, & Andersen, L, 2010). The PAQ scores of children (15.4) in this sample were lower than the range of values (17.5-30.0) that was presented for children in 4^{th} through 6^{th} grades in the instrument reference data (Hay, 1992). The PAQ scores for girls (15.5) in the current study were similar to a sample of adolescent girls (15.2) from the same geographic region; however, boys (15.5) had lower scores than the adolescent boys (24.4) in the comparison study (Klentrou, Hay, & Plyley, 2003). The difference in boys may be due to an increase in opportunities for school sponsored sports teams upon entering middle and high school. Finally, no differences in physical activity participation were observed between genders in the current study. However, significant differences in physical activity have been reported between boys and girls previously using the physical activity participation questionnaire (Klentrou, Hay, & Plyley, 2003), as well as different assessments of physical activity (Belcher et al., 2012; Colley et al., 2011).

Findings from previous studies suggest that the relationship between MP and PA is in general modest, but the explained variance ranges from 1 to 30% of the variance in physical activity (Okely et al., 2001; Graf et al., 2004; Fisher et al., 2004; Reed et al., 2004; Raudsepp & Päll, 2006; Wrotniak et al., 2006; Morgan et al., 2008; Williams et al, 2008; Barnett et al., 2009). Despite being a significant correlate of physical activity participation ($r = 0.19$), MP explained a small proportion of the total variance in physical activity (<1%) in the regression model of this study. Similarly, Barnett and colleagues (2011) found physical activity assessed by questionnaire and locomotor skill performance were weakly correlated ($r =.14$) in adolescents (16.2 years), explaining only 2% of the variance in physical activity. However, object control skill performance (skill requiring control of an object with part of the body or an implement) ($r=.35$, $p<.01$) explained over 12% of the variance in physical activity. This difference in variance may be due to the complexity and ballistic, sport-specific nature of object-control skills compared to the rudimentary nature of locomotor skills.

In general, previous studies suggest that the relationship between MP and PA is modest, but can vary due to the population assessed as evident from the range of variance (Okely et al., 2001; Graf et al., 2004; Fisher et al., 2004; Reed et al., 2004; Raudsepp & Päll, 2006; Wrotniak et al., 2006; Morgan et al., 2008; Williams et al, 2008; Barnett et al., 2009). Stronger correlations have been observed in younger children (Williams et al., 2008) compared to adolescents (Barnett et al., 2009), as well as males compared to females (Morgan et al., 2008). Finally, the utilization of product-oriented MP test and a child-report questionnaire to assess PA may have weakened the relationship in this population as the most robust relationships demonstrated in previous studies (Morgan et al., 2008; Williams et al., 2008) have been those that objectively-measured PA (i.e. accelerometers) and/or used process-oriented MP assessments to determine developmental level.

Besides MP, PAC, specifically addressing the predictive ability of physical self-perception, has also been found to explain 7 to 29% of the variance in physical activity levels of children (Roberts, Kleiber, & Duda, 1981; Crocker, Eklund, & Kowalski, 2000; Davison, Downs, & Birch, 2006). In the current study, PAC was the most robust correlate of PA in both boys and girls with the explained variance (~17%) falling within the range of previous investigations (i.e., 7-29%). Crocker, Eklund, & Kowalski (2000) found that self-perceptions of physical conditioning and sport skills had moderately strong correlations (r = .46 to .48) with 7-day PA recall scores in 10-14 year old Canadian youth. These findings are in close agreement with the current study utilizing similar methodologies. In a longitudinal study, Davisson, Downs, and Birch (2006) observed a slightly weaker correlation (r = .27) between perceived motor competence of girls at 9 years of age and physical activity at 11 years of age. Barnett and colleagues (2011) assessed physical activity participation in relation to perceived sports competence in 215 adolescents and found a moderate correlation (r =.31) with MVPA. The findings from these previous investigations and the current study confirm that PAC is a moderate predictor of physical activity; however, the strength of the relationship may vary by age. When children experience successful performance of fundamental motor skills they may display improvements in PAC (Ulrich, 1987). Further, the mastery of fundamental motor skills may also increase motivation to be physically active due to improvement of self-esteem and enjoyment in participation (Okely, Booth, & Chey, 2004).

The MP abilities (D'Hondt et al., 2011; Graf et al., 2004; Mond et al., 2007; Okely et al., 2004) and PAC (Morano et al., 2011; Jones et al., 2010) of overweight and obese children are generally lower in comparison to their normal weight peers. The current study also found an inverse relationship between BMI and both MP and PAC. However, the relationship was stronger for MP ($r = -.316$ (boys), $p<.001$; $r = -.237$ (girls), $p<.001$) than PAC ($r = -.044$ (boys), N.S.; $r = -.071$ (girls), $p<.05$).

The bivariate relationships discussed above between MP, perceived motor competence, BMI and physical activity have been summarized by Stodden et al (2008). Further, the synergistic relationship between MP and perceived motor competence (Toftegaard-stoeckel, Groenfeldt, & Andersen, 2010; Liong, Ridgers, & Barnett, 2015) has also been found in children. Therefore, it was proposed that the three-way interaction between PAC, MP, and BMI may explain a considerable amount of the physical activity participation of children. However, neither the 3-way interaction term, nor any lower level 2-way interactions were significant predictors of physical activity participation as hypothesized. Similarly, Morgan et al. (2008) assessed the amount of variance that chronological age, BMI z-score, motor competence, and PAC could explain in objectively-measured PA in obese youth. Object-control proficiency explained 25% and 10% of the variance, respectively, of accelerometer counts per minute and % of observed time spent in VPA for boys. For girls, age was the only significant predictor of MPA and VPA, explaining 38% and 15%, respectively. BMI z-score and PAC were not identified as statistically significant correlates of physical activity. All two-way interactions between age, MP variables, and BMI z-score were assessed as covariates of MPA, VPA, and CPM, but none were found to be significant. The results of the Morgan study provide support that chronological age and MP assessed with a process-oriented instrument could be a significant correlates of objective-measured physical activity during childhood. However, the subjects in this study were enrolled in an obesity intervention and thus may not be representative of the general population of obese children or the general population. The current study undertook a similar investigation using a representative sample of youth across the BMI spectrum. The results indicated that PAC had a much greater ability to predict physical activity participation in children than actual MP, SES, and BMI. Therefore, targeting improvements in PAC may be a worthwhile objective in physical activity interventions for OWOB children who have reached an age where limited plasticity in MP exists (Clark & Whitall, 1989; Gutteridge, 1939) such as that in the current study.

Previous intervention programs specifically targeting overweight and obese children and adolescents have shown improvements in both motor performance and perceived athletic competence outcomes (Cliff et al., 2007; Morano et al., 2014). In a 10-week intervention (Cliff et al., 2007) significant pre to post-program improvements in gross motor quotient and perceived athletic competence were found in thirteen overweight and obese children (10.4 years ± 1.2 years) and were still apparent at 9-month follow-up. However, despite the improvements in motor performance and athletic perceived competence, the program did not demonstrate the ability to reduce BMI or improve PA participation. In fact, there was a significant decline in minutes of MVPA from baseline to post-program and again from post-program to follow-up. However, an outpatient clinical program in Italy assessed forty-one children (9.2 ± 1.2 years) before and after an 8-month, 80 session physical training program (Morano et al., 2014). Significant increases were observed in PA, MP, and PAC, while BMI decreased. Findings from these intervention programs indicate that PAC and MP abilities can be improved in overweight and obese children. The greatest improvements were typically associated with programs of longer duration, but regardless of program length, improvements in MP abilities and PAC deteriorated by long-term follow-up. Further investigation into the long-term impact these intervention programs have on PA participation and associated correlates (MP, PAC, weight status/body composition) is warranted.

The current study had several limitations. There were multiple staff conducting the anthropometric assessments and inter-rater reliability was not determined. However, there was a consistent training and testing protocol. Several participants in the original PHAST study had incomplete data and there were significant mean differences in MP and PAC between those with and without complete data, which could have biased the sample in this analysis. Finally, there are a variety of instruments (objective vs. subjective measure) available to assess physical activity participation of children. Instruments used to define the associated correlates (body composition, MP, PAC, perceived motor competence) of physical activity also vary in sophistication and utility. In the current study physical activity participation was evaluated using a validated, self-report measure in the current study. Despite this instrument showing good test-retest reliability it did not possess the strength of correlation with the correlates of physical activity analyzed in this study that previous studies using objective measures have shown. Finally, motor performance was assessed using a product-oriented test which may not have sufficiently assessed the developmental motor proficiency of fundamental motor skills that a process-oriented instrument typically does.

Despite these shortcomings, there were also several strengths of this study. This study was the first to assess the interactions between BMI, PAC, and MP in a large representative sample of children, which allows for improved generalizability to the general population. Subjects in this study were older than the development age of 7.9 years at which motor development abilities have been suggested to begin stabilizing and approach the mature state (Scammon, 1930; Gutteridge, 1939; Clark & Whitall, 1989). Therefore, the impact of developmental age on MP may have been reduced.

Motor performance abilities have been previously identified as an important target when attempting to increase physical activity levels of children and adolescents (Cliff et al., 2007; Graf et al., 2008; Bellows et al., 2013); however, the perception of one's ability to perform motor skills should not be overlooked. The synergistic relationship between perception of MP and actual MP has been highlighted and should be considered when designing interventions. This study showed that PAC is an important predictor of physical activity in all children and specific attention should be given to improving self-perception of motor abilities in overweight and obese children. When children have a sense of confidence and self-belief in their ability to engage in sports skills they will be more likely to participate in physical activity.

Although the results of this study indicate that only PAC has an impact on the physical activity levels of children, a strong repertoire of MP abilities has also been documented to promote physical activity in obese children (Morgan et al., 2008). Further, poor motor ability and low perception of physical ability may impact a child's psychological outlook and both current and future participation in leisure physical activity and recreational sports. The differences in MP and PAC across weight status may be one specific reason for the steep decline in physical activity frequently observed during adolescence (Eaton et al., 2012). Longitudinal studies may be necessary to identify how these two correlates impact physical activity participation by weight status across the childhood and adolescence.

APPENDICES

APPENDIX A:

MANUSCRIPT FIGURES & TABLES

Table 2. Descriptive characteristics of participants with complete and incomplete data.

	TOTAL		COMPLETE DATA		INCOMPLETE DATA	
Variable	n =	Mean (SD)	n =	Mean (SD)	n =	Mean (SD)
Decimal age (yrs)	2190	9.9 (0.4)	1881	9.9 (0.4)	309	9.9 (0.4)
Height (cm)	2189	139.3 (6.5)	1881	139.4 (6.5)	308	139.1 (6.7)
Weight (kg)	2190	36.4 (9.0)	1881	36.4 (8.9)	309	36.4 (9.2)
Body Mass Index (kg/m^2)	2189	18.6 (3.5)	1881	18.6 (3.5)	308	18.6 (3.6)
Body mass Index percentile	2189	62.0 (28.7)	1881	62.1 (28.6)	308	61.2 (29.8)
Perceived athletic competence	2176	18.4 (4.1)	1881	18.5 (4.1)*	295	17.9 (4.1)
Motor performance percentile	1977	66.2 (30.3)	1881	66.9 (30.0)*	96	52.5 (33.6)
Average area household income ($)	2074	70547.45 (21566.97)	1881	70643.13 (21565.57)	193	69614.87 (21614.41)
Physical activity participation score	2177	15.4 (6.7)	1881	15.4 (6.7)	296	15.2 (6.9)

*** $p<0.05$**

Table 3. Descriptive characteristics for the total sample and boys and girls in the analytic sample.

	TOTAL		BOYS		GIRLS	
Variable	n =	Mean (SD)	n =	Mean (SD)	n =	Mean (SD)
Decimal age (yrs)	1881	9.9 (0.4)	955	9.9 (0.4)	926	9.9 (0.3)
Height (cm)	1881	139.4 (6.5)	955	139.5 (6.2)	926	139.3 (6.9)
Weight (kg)	1881	36.4 (8.9)	955	36.3 (8.5)	926	36.5 (9.3)
Body Mass Index (kg/m^2)	1881	18.6 (3.5)	955	18.5 (3.4)	926	18.6 (3.6)
Body Mass Index percentile	1881	62.1 (28.6)	955	63.6 (27.4)*	926	60.6 (29.6)
Underweight	34	1.8%	12	1.3%	22	2.4%
Normal weight	1279	68.0%	654	68.5%	625	67.5%
Overweight	297	15.8%	151	15.8%	146	15.8%
Obese	271	14.4%	138	14.5%	133	14.4%
Perceived athletic competence	1881	18.5 (4.2)	955	19.1 (3.9)*	926	17.8 (4.3)
Motor performance percentile	1881	66.9 (30.0)	955	71.2 (29.0)*	926	62.6 (30.4)
Average area household income ($)	1881	70643.13 (21565.57)	955	70645.23 (21844.44)	926	70640.97 (21285.94)
Physical activity participation score	1881	15.4 (6.7)	955	15.5 (6.9)	926	15.2 (6.5)

*** p<0.05**

Table 4. Bivariate correlation coefficients between physical activity and potential correlates in boys (n = 955) and girls (n = 926)

	Perceived Athletic Competence		BOT-MP percentile		BMI		Average area household income	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
PA participation questionnaire score	0.413 ***	0.420***	0.191***	0.185***	0.038	-0.071*	0.116***	.050**
Perceived Athletic Competence			0.267***	0.224***	-0.044	-0.071*	0.084 **	0.0911
Motor performance percentile					-0.316***	-0.237***	0.093**	0.056*
Body Mass Index							-0.055*	-0.042
Average area household income								

* = p <.05; ** = p<.01; *** = p<.001

Table 5. Significant main effects for correlates of physical activity participation of boys (n = 955) and girls (n = 926)

Boys	Unstandardized β	p-value	Variance explained
Model A			Model adjusted R^2 = .183
Perceived athletic competence	.688 (.054)	.000	adjusted R^2 =.170
Motor performance	.028 (.008)	.000	adjusted R^2 =.006
Body mass index	.183 (.062)	.003	adjusted R^2 =.007
Model B			Model adjusted R^2 = .188
Perceived athletic competence	.679 (.054)	.000	adjusted R^2 =.170
Motor performance	.027 (.008)	.000	adjusted R^2 =.006
Body mass index	.188 (.062)	.002	adjusted R^2 =.007
Socioeconomic status	.0000247(.000)	.008	adjusted R^2 =.005
Girls			Model adjusted R^2 = .183
Perceived athletic competence	.595 (.046)	.000	adjusted R^2 =.175
Motor performance	.021 (.007)	.002	adjusted R^2 =.008

APPENDIX B:

EXPLORATORY AIM

Exploratory aim: Examine the physical activity participation of children across eight groups created by weight status classification and median split of both perceived athletic competence (PAC) and motor performance (MP). It is hypothesized that overweight and obese children with low MP and/or low PAC will engage in significantly less physical activity compared to overweight and obese children with better MP and PAC. Further, normal weight children with higher levels of MP and PAC will engage in the highest amount of physical activity.

Despite findings no significant interactions between PAC, MP and BMI in the interactions model conducted within these dissertation, examining the negative spiral of disengagement and positive spiral of engagement of overweight/obese and normal weight children illustrated in the Stodden model (Fig. 1) is of particular interest to the author. Recently, the author and colleagues (Morrison et al., 2012) completed an analysis of the joint association between weight status and motor performance on the physical activity levels of children. The results demonstrated that Danish boys (mean age = 6.8 yrs) with lower motor skill scores and higher percent fat engaged in significantly less ($p < .05$) physical activity than peers who had higher motor skill scores and similar adiposity. However, the sample was lean (mean %fat = 13.6% in males; 15.7% in females) physically active, ethnically homogenous sample, and a marker of perceived athletic competence was not recorded. It is of interest to investigate whether these findings are supported in a more heterogeneous sample including overweight and obese individuals, where perceived athletic competence has been assessed.

Gender-specific ANCOVAs (controlling for age and SES) were used to compare physical activity participation across eight groups, which were created by clinical classification of BMI as normal weight (NW) 0 percentile to $<85^{th}$ percentile or overweight/obese (OWOB) $\geq 85^{th}$

percentile and median split of both perceived athletic competence (PAC) and motor performance (MP). Median values were 20.0 and 18.0 for the PAC variable and 84.00 and 70.50 for the MP variable for girls and boys, respectively. Values equal to or above the median were classified as "high", whereas those values below the median were classified as "low". The eight groups will be categorized as: NW/Low PAC/ Low MP; NW/Low PAC/High MP; NW/High PAC/Low MP; NW/High PAC/ High MP; OWOB/ Low PAC/ Low MP; OWOB/ Low PAC/High MP; OWOB/ High PAC/Low MP; OWO/ High PAC/High MP. Effect sizes were calculated to determine the significance of difference between groups.

Figures 3 & 4 display the group means for physical activity when subjects were cross-tabulated by weight status, PAC, and MP. Individuals in the NW/High PAC/High MP classifications had significantly ($p<.001$) greater mean physical activity participation scores than their counterparts in the OWOB/Low PAC/Low MP group regardless of gender. Further, both boys and girls classified as High PAC had significantly ($p<.001$) greater mean physical activity participation scores than individuals classified as Low PAC, regardless of weight status and MP classification. Finally, boys in the NW/High PAC/High MP group significantly ($p =.017$) greater physical activity participation than boys in the NW/High PAC/Low MP. Similar results were observed for girls in the NW/Low PAC/High MP group demonstrating a significantly ($p =.033$) greater mean questionnaire score than NW/Low PAC/Low MP group.

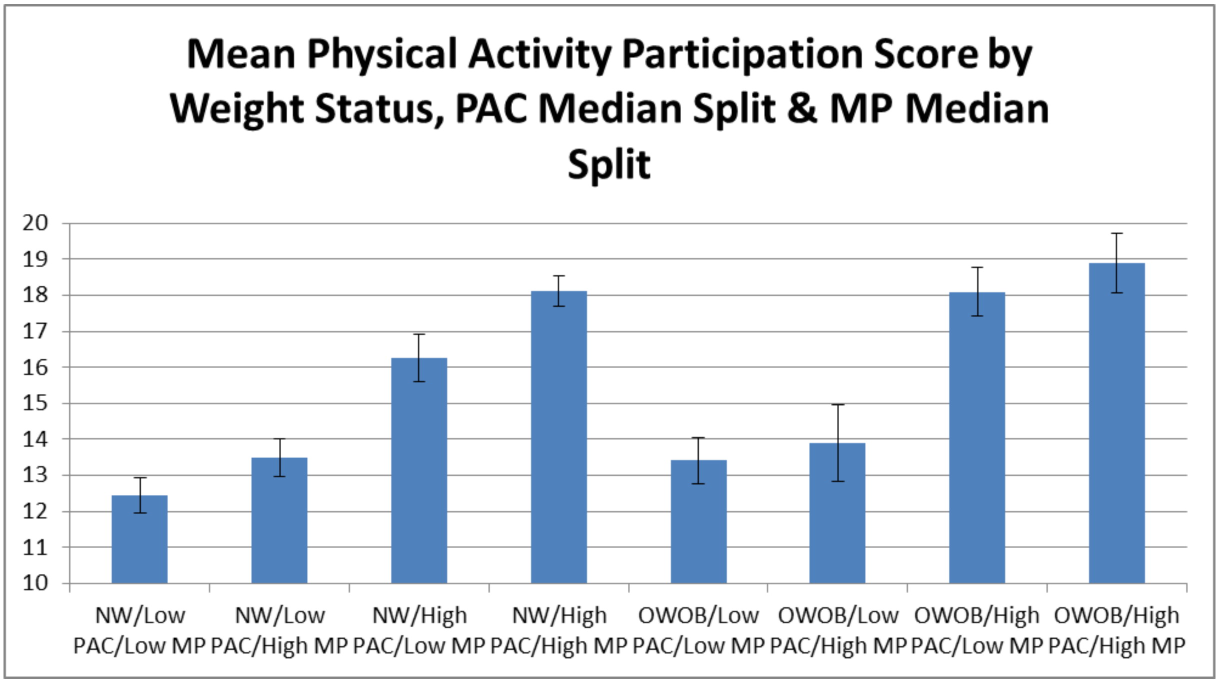

Figure 4. Mean physical activity participation score for boys by weight classification, perceived athletic competence median split, and motor performance median split

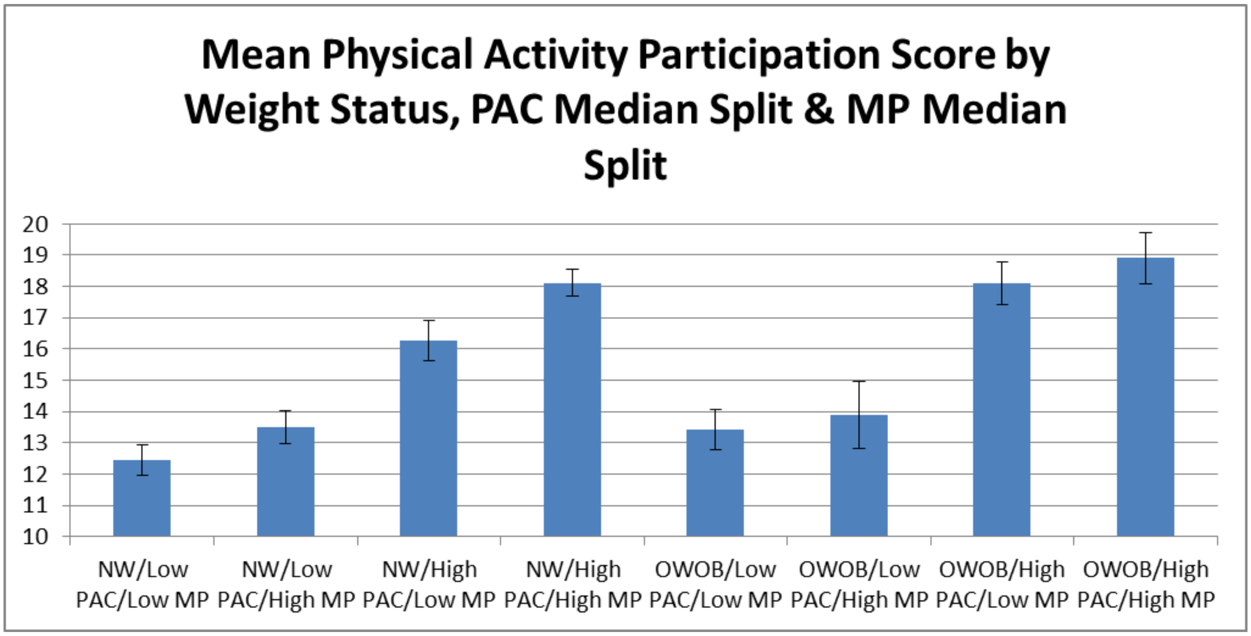

Figure 5. Mean physical activity participation score for girls by weight classification, perceived athletic competence median split, and motor performance median split

Despite the lack of interactions between the variables included in the correlational and regression models within the dissertation, we examined the combined influence via bimodal/clinical classification of predictors (NW vs OWOB; High/Low MP and PAC) that are illustrated in the positive spiral of engagement and negative spiral of disengagement proposed by Stodden and colleagues (2008). The joint association between the three correlates demonstrated meaningful differences amongst the various groups. In particular, there was a significant difference between the OWOB/Low PAC/Low MP and Normal weight/High PAC/High MP. This support the supposition that when children reach an unhealthy weight status characterized by low PAC and poor MP they could be at risk for further disengagement from a physically active lifestyle when an additive impact from each negative attribute. In conclusion, these findings suggest that improving PAC may be beneficial in increasing the physical activity participation of both NW and OWOB children, but higher MP abilities may only significantly impact PA participation in normal weight children. However, a strong repertoire of motor skills should not be overlooked in early and middle childhood.

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CHAPTER 4: SUMMARY & FUTURE DIRECTIONS

SUMMARY

The overall objective of this dissertation was to provide a better understanding of the association of motor performance, perceived athletic competence, body mass index or weight status with physical activity levels among normal weight and overweight and obese children and adolescents. Further, the interrelationships among physical activity, weight status, motor performance and perceived athletic competence in children were further examined.

The bivariate relationships between physical activity and associated correlates have been previously established in the literature. This study showed that perceived athletic competence was moderately correlated of physical activity and explained ~17% of the variance in physical activity. These findings concur with previous research on this relationship. In contrast, neither body mass index nor motor performance demonstrated the ability to explain meaningful amounts of the variance in physical activity. There was however a moderate inverse relationship between body mass index and motor performance.

A novel aspect of this study was the analysis of the interactions between body mass index, perceived athletic competence and motor performance to predict physical activity participation in a representative sample of youth. This investigation did not find any of the interaction terms to be significant predictors of physical activity despite a modest correlation between motor performance and perceived athletic competence.

The findings from this dissertation support the necessity of developing resilient perceived athletic competence in the promotion of childhood physical activity during later childhood. Further, targeting improvements in perceived athletic competence could be especially helpful when working in intervention programs for overweight and obese children. However, emphasis should still be put on physical education and other opportunities for motor skill development,

especially in early (3-5 years old) through middle (5-8 years old) childhood due to the increased plasticity of neurological systems and potential improvements in skill performance (Gutteridge, 1939; Scammon, 1930) previously discussed. Stronger motor performance abilities could lead to stronger self-perceptions of motor abilities, which could lead to greater participation in physical activity.

FUTURE DIRECTIONS

One of the major limitations of this dissertation and the associated literature is the variation in instrumentation and markers used to assess children's physical activity and the associated correlates. There is a need for consistent utilization of validated assessments in pre- and post-testing. This dissertation sought to implement dependable, conventional assessment and statistical techniques, but as identified the findings may have been limited by the instrumentation utilized to assess physical activity, motor performance, and perceived athletic competence. When analyzing the previous literature it can be concluded that use of objective measures of physical activity and process-oriented motor performance batteries provide valid assessment of intra-individual variation and strong associations with one another. Measures of perceived motor competence exist and need to be routinely implemented instead of using substitutions, such as perceived athletic competence, that only capture a portion of the desired construct.

As previously stated, the findings from this dissertation could assist in the development of strategies within multi-disciplinary intervention programs that aim to promote physical activity participation in overweight and obese children. A series of interventions by Robinson and colleagues (Robinson & Goodway, 2009. Robinson, Rudisill & Goodway, 2009; Robinson, 2011) was undertaken targeting improvements in the perceived physical competence and object control motor performance of preschool children. Mastery motivational climate was utilized in experimental groups and led to significant improvements in both outcomes. Instructional techniques within these classrooms were rooted in motivation achievement theory (Ames, 1992) and are based on the TARGET (task, authority, recognition, grouping, evaluation, and time) approach (Epstein, 1988). This method allows the student to gain autonomy and self-direct themselves through a planned curriculum with the goal of mastery learning. Due to the deficits in both perceived motor competence and object control skill proficiency that have been observed in overweight and obese youth, this instructional style could lead to potential improvements. Conducting a physically activity intervention in a clinically obese population (BMI >85th centile for age and gender) using the TARGET approach could assess changes in physical activity participation in relation to improvement in associated correlates.

The relationships surrounding physical activity, body mass index, motor performance, and perceived motor or athletic competence that have been reported in previous investigations as well as this dissertation study have primarily utilized cross-sectional approaches. It would be worthwhile for researchers to conduct longitudinal measurement of the physical activity levels and associated correlates in normal weight and overweight/obese through childhood and adolescence. These investigations would provide evidence on the trajectories of individuals who possess various positive or negative traits related to weight status, motor performance, and perceived motor or athletic competence. Longitudinal analyses of effectiveness of interventions such as those discussed in the previous paragraph could also be meaningful.

Finally, as a follow-up to the current study it would reasonable to consider the correlates addressed within this study, as well as other markers promoting physical activity (e.g., physical fitness) in the framework of physical literacy. Physical literacy is defined as "the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life (Whitehead; 2013).” Longmuir and colleagues (2015) recently developed a calculation process for the Canadian Assessment of Physical Literacy (CAPL) for children ages 8 to 12. The CAPL assess factors related to physical literacy in four domains: physical competence (health-related fitness and motor performance), motivation and confidence toward physical activity, measures of daily behaviors (physical activity and sedentary activity), and knowledge/understanding of an active lifestyle. The data from PHAST study data includes markers of three of the four domains of the traditional physical literacy definition, but to the author’s knowledge does not possess a measure of each participant’s knowledge/understanding of an active lifestyle. However, it would be an interesting follow-study to assess differences in physical activity participation or weight status based on the calculation of a physical literacy score from the PHAST data.

The author hopes to address the potential research questions discussed with the line of research he will pursue during his career.

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