1-1-2011

Objective physical activity and sleep characteristic measurements using a triaxial accelerometer in eight year olds

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OBJECTIVE PHYSICAL ACTIVITY AND SLEEP CHARACTERISTIC MEASUREMENTS USING A TRIAXIAL ACCELEROMETER IN EIGHT YEAR OLDS

by

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DISSERTATION

Submitted to the Graduate School

of Wayne State University,

Detroit, Michigan

in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

2011

MAJOR: NURSING

Approved by

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Advisor Date

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DEDICATION

Although, many people have walked this journey with me, I especially dedicate this dissertation and the completion of my doctoral work to my family. Their support and encouragement fueled my endeavors.

Completion of this work would not have been possible without the patience and love of my best friend and husband, Mark. He did whatever needed to be done to free my time for the endless hours of study. He listened attentively to my writings and stood by me when it seemed as though this work was a never-ending journey. I could not have completed without his selfless commitment, tireless support, incredible patience, and perpetual encouragement.

My five children have been a constant source of strength to me. Not only have they given me thousands of reasons to be profoundly proud of them, they held me firm to the belief that quitting is always a sign of weakness.

I am particularly grateful to my parents; my mother for instilling within me the values of determination and faith to pursue my dreams and my father for impressing upon me the ultimate importance and power of education. I think of my father always and miss him every day.

I am thankful to my study participants and the third grade teachers that worked so diligently with me. The information we acquired will be shared with other children in the hopes of improving their futures and health outcomes.

ACKNOWLEDGMENTS

First and foremost, I would like to acknowledge Dr. Jean Davis, my advisor and the chairperson of my dissertation committee. I am fortunate to have had a mentor that “put training wheels” on my bike through this journey until I was steady enough to ride on my own. Her insightful comments and valuable feedback impressed upon me her passion for scientific inquiry and scholarship. The encouragement, kindness, and guiding support she showed me were invaluable throughout the development of my research and academic skills. The sharing of her knowledge in the area of sleep and her detailed teaching of the research process during my dissertation was paramount in assisting to develop depth and direction in my own research. It has been an honor and a privilege to work with and learn from her.

Next, I would like to thank my committee for the guidance they provided me throughout my dissertation process. Specifically I would like to thank Dr. Nancy George, for her expertise in the area of research with young people as well as her input regarding my theoretical framework, Dr. Hossein Yarandi, for his guidance and patience throughout the statistical analysis of the study data, and Dr. Hermann Engels, for his vast knowledge of physical activity. I am grateful for the time and insight my committee shared with me. I would like to extend my deepest thanks for all their input and assistance in helping me bring this project to a successful conclusion.

I would like to thank Dr. Patricia Jarosz, who initially served as my advisor, for her thought-provoking questions and perceptiveness. I would also like to acknowledge the support and encouragement of the faculty and my colleagues at the College of Nursing. They provided encouragement and support while I was working on this degree.

I would like to thank my research assistant, Joan Bickes. She was attentive to the needs of the charter schools as they sent her the master list. She maintained the anonymity of the study as she sent the confidential, unnamed list of students to me. Data was expeditiously processed.

I would like to acknowledge the Graduate School of Wayne State University for funding this project with a Dissertation Support Award and for the receipt of the Summer Dissertation Fellowship 2011. I further gratefully acknowledge Sigma Theta Tau International, Lambda Chapter, and Blue Cross and Blue Shield of Michigan Foundation Student Award Program (#1575.SAP) for assisting in the financing of the pilot study to this dissertation. Valuable information and subsequent success to the continued research through the dissertation was appreciated by this preliminary study.

Lastly, I would like to extend my appreciation to the three charter schools in Detroit that continue to provide an excellent academic atmosphere for its students and offered me a welcoming and friendly environment for my data collection.

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CHAPTER ONE

Introduction

Health habits and behaviors are initially contemplated, considered, and rudimentarily acquired in childhood. It is imperative to establish an accurate foundation of knowledge. A broad range of health effects is contingent on the precise implications of evidence-based recommendations, specifically for physical activity and sleep patterns. Currently, the guidelines and recommendations in place for children are the result of data collected mostly in the form of self-reports. The accuracy of testifying to one's own activity frequencies, durations, and intensities as well as sleep duration has been shown repeatedly to be highly inaccurate. Consequently, the question of precision, especially as these guidelines relate to health outcomes during childhood, is questionable.

Measurement issues and methodological inconsistencies must be addressed initially before appropriate interventions can be implemented. Quantification and qualification of physical activity dimensions and sleep characteristics are essential not only for the purpose of clearly establishing parameters for recommendations but also for the intent of verifying optimal health outcomes related to conditions of energy balance. Energy balance can be described as a continuum of collaborative ingredients, gradually evolving through variations and transitions. Health outcomes related to energy balance pertain here to weight status. It is a state in which the total energy intake equals total energy needed, by balancing the number of calories consumed with the number of calories used. Energy expenditure occurs to varying degrees throughout various activities. Physical activity is the most common form of energy expenditure in humans and sleep is the most familiar restorative form of energy expenditure. In an effort to establish appropriate and accurate physical activity guidelines, it is mandatory to objectively quantify the dimensions of physical activity and the characteristics of sleep required to maintain this energy balance. Physical activity accounts for a large measure of energy expenditure in free-living, unstructured behaviors. Free-living physical activity is considered to be independent existence and movement in a community environment. The most frequently seen free-living physical activity is walking. Insufficient activity contributes to an energy imbalance, weight status gain, and consequently the obesity epidemic in the United States (Dietz, 1998). Poor health outcomes related to weight status or excess fat accumulation is widely attributable to a chronic energy imbalance. Disruption in this energy balance impacts various arenas in a child's life. These assorted arenas in a child's live can be measured and classified as health indicators and psychosocial indicators.

Physical activity and sleep parameters as recommended for optimal health outcomes and needed for the maintenance of an energy balance, may or may not give accurate counsel when they are the consequence of historically misleading self-reports. Sleep, like physical activity, appears to be a factor that alters both sides of the energy balance equation. There is increasing evidence that short sleep duration may contribute to the progression of an energy imbalance (increased weight status as a health indicator) as well as a decline in academic markers such as achievement and behavior (academic scores and school attendance as psychosocial indicators) (Nixon et al., 2008; Taheri, 2006; Touchette et al., 2007). Objective evaluations or assessments of energy balance are undermined without the foundation of objectively defined guidelines.

The importance of accurately calculating the dimensions of physical activity and the characteristics of sleep is to facilitate the clarification of established guidelines and to assist in the evaluation of significant interventions. Risky health-related behaviors (physical inactivity and lack of sufficient sleep) are linked to significant consequences, such as intellectual failures, school absences, and the inability to pay attention in class (Shephard, 1996). There is a deficiency in research-based information regarding how academic achievement is influenced by physical activity, sleep, and weight status and vice-versa (Bandini, Must, Phillips, Naumova, & Dietz, 2004; Dietz, 2005; Nixon et al., 2009; Taheri, 2006).

The consequences of vague or inaccurate guidelines track to future generations. Risk factor tracking is the increased likelihood that a particular experience(s) will be followed. Although the concept of risk factor tracking is well established, a fairly recent notion is that behavioral risk factors also track and tend to accumulate in either health promoting or health compromising directions. Physical activity practices (positive or negative) that track through childhood contribute to the behavioral health patterns that are sustained in adults (Pate, Baranowski, Dowde, & Trost, 1996). In other words, less active children tend to remain less active throughout their life. No studies have objectively defined, advised, or cautioned the amount of physical activity dimensions (frequency, intensity, and duration) recommended or necessary to prevent such unhealthy sequences of events. The consequences of insufficient physical activity behaviors in childhood may not only implicate weight status in adulthood, but may also implicate sleep and academic achievement in adulthood, as these tracking behaviors are influential for a lifetime (Pate, et al., 1996).

The relationship between the health indicators of physical activity, sleep, and weight status require dependable measures to establish consistent estimates of the dose of activity and sleep needed for specific outcomes or interventions (Freedson, Pober, & Janz, 2005). Resolute measurements speak to the accuracy of the research that guides the policy decisions. Precise objective instrumentation and consistent research techniques benefit the translation of research to policy in the health field. This research will be focused most specifically on the measurement potentials of physical activity dimensions and sleep characteristics in children. As a corollary to this study, guidelines may need to be reestablished or redefined. Health outcomes may need to be revisited since most recommendations are the result of a fairly inaccurate base.

Although health concerns of all children are significant, it is impossible to ignore the differences and risk factors that particular ethnic groups and low income communities face. For example, obesity is rising faster among African-American children than among most other ethnic groups. Obesity increased by more than 120 % among African Americans over the past decade. During that same time, obesity increased among whites by more than 50% (Strauss & Pollack, 2001). African-American parents of children ages 9 to 13 years detail more barriers to physical activity than white parents (Gordon-Larsen, Nelson, Page, & Popkin, 2006). These barriers included transportation, expense, and availability of local opportunities. Communities of color have fewer public recreation facilities, such as parks and community centers, that provide opportunities for physical activity outside of the school day (Gordon-Larsen, et al., 2006). Children spend approximately 30 hours per week in school; current guidelines indicate that at least 30 minutes of moderate-vigorous physical activity should be accumulated during the school day (Nettlefold, McKay, Warburton, McGuire, & Bredin, 2010). Lower income parents report more barriers to their children's physical activity than parents with higher incomes (Ferreira et al., 2007). People who live in areas with more recreation facilities are more physically active and less likely to be overweight or obese (Sallis & Kerr, 2006). Additionally, about one-third of third-grade public school students do not have at least 20 minutes of recess daily, as recommended by NASPE. Students at predominantly black schools were less likely than those at predominantly white schools to have the recommended amount of recess time (Turner, Chaloupka, Chriqui, & Sandoval, 2010). Physical activity guidelines recommend that 40% of the recess and lunch breaks ought to be in moderate-vigorous activity and 50% of the physical education should be conducted in moderate-vigorous physical activity (U.S.D.H.H.S., 2010). Yet recent findings show evidence of very slight proportions of time during physical education is spent in moderate-vigorous activity (Nettlefold, McKay, Warburton, McGuire, & Bredin, 2010).

An area that is generating intense focus is the proposed relationship between short sleep duration and declining physical activity, especially in children. Rising obesity in children is paralleled with falling sleep duration. Plausible mechanisms exist. Short sleep duration could promote obesity via reduced physical, increased energy intake, and/or alterations in hormones. Alternatively, weight status could contribute to short sleep duration or increased sleep disruptions. Additionally, a cofounding rather than causal association may implicate the role of physical activity in the health of children and could decrease sleep duration and increase body mass index. Yet the potentially provoking association between health indicators in children is marred by study design issues and methodology inconsistencies. Sleep research in children is limited and has focused mainly on disorders of selected aspects of sleep, such as obstructive sleep apnea (OSA) or sleep-disordered breathing, rather than on differences related to ethnicity and/or income. Furthermore, measuring duration of sleep in children with parental estimates has created very diverse and potentially inaccurate reports, especially as children age. However, one relatively recent study demonstrated that the relationship between children's academic performance and sleep habits may differ among children of different backgrounds. According to a study by Buckhalt, El-Sheikh, and Keller (2007), low income African American children appear to be more vulnerable to the effects of sleep disruption than higher-income European-American children. Children may not be at equal risk for cognitive difficulties when sleep is disrupted. There ought to be a sense of urgency in confirming or refuting temporal relationships between health indicators and psychosocial (academic) indicators in children. Funding dollars are scarce and interventions are currently in place and being implemented to address the health concerns of children.

Physical Activity Measurements in Children

Basis and History of Physical Activity Recommendations

Current recommendations for children to accumulate 60 minutes or more of physical activity daily are based on epidemiological associations between self-reported physical activity and health outcomes (Troiano, 2005). These national guidelines for children and adolescents solicit any kind of moderate-to-vigorous physical activity that increases heart rate and causes one to breathe heavily (Strong et al., 2005). Much subjectivity and personal discernment is introduced with this type of reporting. Self-reported data estimated that 23-44% of the European population adhered to current physical activity guidelines while accelerometer data reported less than 10% met activity recommendations (Sjostrom, Oja, Hagstromer, Smith, & Bauman, 2006). Self-reporting of physical activity, especially in children, has been shown to have significant bias due to a combination of developmental recall challenges in this age group as well as their desire for social acceptance in their responses. When absolute amounts of physical activity are to be evaluated, self-reports may not be the most acceptable measure (Sallis & Saelens, 2000).

The impact of inadequate physical activity as defined by its objective dimensions and the insufficient exposition of sleep characteristics will result in poorly measured health outcomes, possibly for generations. A brief look at the history of these frequently revised guidelines and recommendations will speak not only to the inconsistency in self-reporting physical activity, but also to the danger of relying on questionable data when drawing a consensus. In 1978, the American College of Sports Medicine (ACSM) issued a position paper, "The Recommended

Quantity and Quality of Exercise for Developing and Maintaining Fitness in Healthy Adults". This was an opinion statement on the amount of physical activity needed for optimal health in the general population (Twisk, 2001). The focus was related to training thresholds and fitness criteria. In 1995, in a collaborative effort between the ACSM, the Centers for Disease Control (CDC), and the American Heart Association (AHA), these guidelines were refined, complemented, and expanded. The 1995 clarification of recommendations on physical activity needs was directed at improvement and maintenance of health in adults only. Consensus was achieved; guidelines were explicitly described, as well as verified by inclusion in *Healthy People 2000.* It was clearly stated that all Americans (adults and children alike) should engage in at least 30 minutes of moderate-intensity physical activity on most (preferably all) days of the week (NIH, 1996). The first ever physical activity guidelines specific to children (Physical Activity for Children: A Statement of Guidelines) were developed by the National Association for Sport and Physical Education, Council for Physical Education for Children (COPEC) (Corbin & Pangrazi, 1998). At the turn of the 21st century, there were additional guidelines published from the International Consensus Conference on Physical Activity as well as national guidelines from the United States Department of Agriculture (USDA), the Department of Health and Human Services (DHHS), the Centers for Disease Control and Prevention (CDC) and the National Association for Sports and Physical Education. In addition, recommendations from the International Association for the Study of Obesity (IASO), with a focus shift to the growing concern related to the prevention of weight gain, suggested that adults ought to accumulate 45-60 minutes of daily moderate to vigorous physical activity (MVPA) and that children do "even more" (Saris et al., 2003). The first ever physical activity guidelines issued by the federal government were released by the U.S. Department of Health and Human Services (HHS) in 2008

(CDC, 2008). Due to the lack of empirical scientific evidence, however, the above referenced studies and national guidelines were the result of self-reported estimates of national activity levels and as a result were predisposed to uncertainty, necessitating frequent revisions and changes.

Compliance with these guidelines was evaluated in several studies and national surveys, such as the Youth Risk Behavior Surveillance (YRBS) (Brener, Grunbaum, Kann, McManus, & Ross, 2004; Grunbaum et al., 2004). These surveys were administered to only youth who attended school. Consequently, this data is again lacking full disclosure from this cohort and is not representative of all persons in this age group. The extent of under reporting or over reporting of behaviors can also not be determined, resulting in nebulous compliance reporting. The challenging process of objectively evaluating the physical activity of children is compounded by their distinctive movement patterns and unique metabolic needs. Knowledge about the health benefits of habitual physical activity in children has led to the relatively recent formation of public health guidelines. Increases in the daily levels of moderate-vigorous physical activity intensity in youth speak not only to methods of health promotion but also addresses strategies that assist in the prevention of disease.

Physical Activity as a Health Indicator

Physical Activity Defined in Children

Physical activity is defined as a complex, multifaceted set of behaviors that encompass any bodily movement produced by the contraction of skeletal muscle that results in energy expenditure above resting levels (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2008; Caspersen, Powell, & Christenson, 1985; Kohl, Fulton, & Caspersen, 2000; Shephard, 2003). Physical activity takes place in four dimensions: intensity (rate of energy expenditure), frequency (number of sessions per unit of time), duration of time (recorded in arbitrary units), and type (a qualitative descriptor) (Must & Tybor, 2005). Physical activity and energy expenditure are not equivalent. Physical activity is considered a behavior and energy expenditure is the calculated energy cost of that behavior (Hu, 2008). Energy expenditure is a result of physical activity. It is a composite measure of physical activity that takes into account activity dimensions and individual demographic variables (Welk, 2002). Therefore, total physical activity is a function of the type of stimulus, purpose of movement, the intensity at which the stimulus is performed, the efficiency of the action, the duration, the frequency, and the specific energy costs of the activities performed.

In actual practice, the specific operational definition of physical activity depends on how it is measured and scored through the variables of frequency, intensity and duration (Welk, Corbin, & Dale, 2000). To accurately assess children's activity patterns, an instrument(s) must be sensitive enough to detect, code, or notate periodic, intermittent activity. There remains no single way of consistently obtaining a highly accurate account of physical activity in children. The nature of children's movement patterns, the various types of activities engaged in, and the inherent limitations of each assessment tool limit the ultimate accuracy of measurements (Welk, Corbin, & Dale 2000).

Use of Accelerometers in Children

Interest in monitoring the acceleration of the body started in the 1950's when an association between the integral of vertical acceleration versus time and energy expenditure was suggested (Dishman, Washburn, & Schoeller, 2001). The first objective measurements through use of a motion sensor, in an attempt to evaluate the physical activity levels of children, were reported in 2003 (Jackson et al., 2003). This study confirmed the practical use of the accelerometer and its potential to objectively reveal important insights into the physical activity patterns and energy expenditure in young children. The ActiGraph accelerometer was used in the first objective measurement of physical activity in a *nationally* representative (7000+) health survey (2003-2004 National Health and Nutritional Examination Survey; NHANES). This data was qualitatively consistent with self-reports. However, absolute counts, frequencies, durations and bouts of physical activity as recorded on the accelerometers revealed dramatically dissimilar and contrasting adherence results. Less than 10% of adolescents as measured by accelerometers actually met the national recommendations of 60 minutes per day of moderate to vigorous activity (Troiano, et al., 2008). Although the results were qualitatively consistent with the age and gender specific self-reports, the findings were dramatically dissimilar from the prevalence and adherence outcomes according to the accelerometer readings (Troiano, et al., 2008). These findings confirmed the belief that most children are not sufficiently active to attain optimum health (Sleap & Tolfrey, 2001).

Measurement of physical activity among younger children remains a challenge as it transpires in an environment of growth and developmental changes. The study of physical activity in children is complicated by developmental differences, immature vocabulary, and unique activities specific to children (Pearce, Harrell, & McMurray, 2008). Children are inherently active primarily because it is physical movement that provides them with the necessary information required by the central nervous system for stimulation (Eston, Rowlands, & Ingledew, 1998). Youngsters have an innate biological need to be active. Short intermittent periods of vigorous physical activity are typical of children and in fact may be necessary for normal growth and development (Bailey et al., 1995). Activity bouts are temporary, brief episodes of time spent in a particular intensity of physical activity. Activity patterns in young children are typically random and intermittent, with frequent bouts of brief exercise and erratic transitions from high to low intensities (Bailey, et al., 1995). There is limited information available on the specific energy costs of different activities in children, making it difficult to translate activity information to energy expenditure (Goran, 1998).

Increased sensitivity of measurement, consistency of methods, and consensus of recommendations are needed to measure physical activity dimensions (frequency, duration, and intensity) and domains (settings and locations) in children. Volume (duration), intensity (rate), and frequency are dimensions of physical activity cumulatively needed by researchers to understand the dose response of physical activity on a health outcome. Research efforts have as yet not combined physical activity dimensions, cumulatively or synergistically, in any one analysis. In the most recent Cochrane Systematic Review summarizing the effectiveness of school-based physical activity interventions, yet there were no studies cited that analyzed two or more of the physical activity dimensions in one research project (Dobbins, DeCorby, Robeson, Husson, & Tirilis, 2009). In any given study, one objective physical activity measure was used to examine one physical activity dimension, either intensity, rate, or duration. Motion sensors were only used in a total of three studies cited in this Cochrane Review, and these three studies demonstrated significant correlations between the physical activity (intensity or rate) intervention and the study specific outcome of BMI and/or heart rate (Ewart, Young, & Hagberg, 1998; Stone et al., 2003; Verstraete, Cardon, DeClerq, & DeBourdeaudhuij, 2007).

Lack of standardized procedures related to placement of the motion sensor continues to be unresolved. The motion sensor monitor has generally been placed in one of three places on the body, the wrist, the ankle, and/or the waist. A very small number of studies have specifically addressed the implications related to the issue of monitor placement. Few studies have rigorously evaluated the issue of monitor placement in children. A variety of inconsistent associations between acceleration data and energy expenditure have been demonstrated using different body segments for motion sensor attachment (Trost, McIver, & Pate, 2005).

Another area of accelerometer use that has captured discussions of controversy is the appropriate length of an epoch. The typical length of an epoch or time interval used with a motion sensor to evaluate physical activity is one minute. The concern with this length of time (epoch) in children is the possible inability of capturing bursts of activity, bouts, which are typical in this age group. Objectively obtained estimates of physical activity yielded very different values, dissimilar activity patterns, and decreased guideline adherence when compared with those obtained by commonly used self-reports (Hagstromer, Oja, & Sjostrom, 2007). No specific criterion has been defined as to what constitutes regular activity or bouts of activity in children.

No consensus on data gathering techniques, significance of levels of activity dimensions, and interpretation of objective measurements has been reached. No one study has concurrently gathered data on intensity, frequency, and duration of physical activities. No one study has explored the thorough capabilities of objective monitoring of physical activity in eight-year-olds, particularly with a triaxial accelerometer, despite the implications that the triaxial accelerometer offers greater prediction accuracy of energy expenditure during free-living activity (Ott, Pate, Trost, Ward, & Saunders, 2000; Plasqui, Joosen, Kester, Goris, & Westerterp, 2005). A triaxial motion sensor is an activity monitor that collects motion data on three axes; it is intended for the simultaneous measurement of accelerations in three planes. No studies have used a triaxial accelerometer for a 24-hour period in children to evaluate the implications of a circadian pattern of movement, from physical activity to sleep.

One of the fundamental questions critical to understanding the meaning of physical activity assessed by a motion sensor is how to translate and interpret the signal into meaningful data that can be linked to a health outcome. The accelerometer stores raw acceleration data, which then needs to be translated into a metric that is anchored to a biological variable, namely energy expenditure. This task is particularly difficult in children because growth and maturation confound associations. The metabolic cost of movement expressed relative to body mass decreases as children mature. Children have higher metabolic rates than adults, attributable to higher stride frequency and less efficient economy of locomotion (Puyau, Adolph, Vohra, & Butte, 2002). No physical activity compendium for children has been agreed upon or developed for intensity thresholds or energy expenditure in children. The data that is obtained from an accelerometer needs to be optimized for all its potential and standardized for measurements and procedures.

Sleep as a Health Indicator

Children and Sleep

Sufficient sleep is increasingly being recognized as an essential aspect of health promotion and chronic disease prevention. According to the National Sleep Foundation, published sleep requirements and guidelines are based on how much time an individual spends in bed, as narrated by self-reports. Individual variations, cultural differences, secular changes, and actual time spent sleeping are not taken into account in published sleep guidelines.

Children appear to have acquired unfavorable shifts in activity over time, less sleep and more sedentary behaviors. National Sleep Surveys have shown a one to two hour reduction in self-reported sleep times over the past thirty to fifty years (Cappuccio et al., 2008). The widespread secular notion that children are sleeping less has been ascribed to a number of explanations related to the modernization of our society, such as increased use of technology and inconsistent and unpredictable contemporary lifestyles (Ferrara & De Gennaro, 2001). Indeed, research confirms that shorter sleep time has been associated with more media use and reaffirms the fact that 43% of school-aged children have televisions in their bedroom (Carskadon, Mindell, & Drake, 2006).

Sleep duration is affected by multiple factors which may be difficult to control and/or measure. Confounders may be embedded within a familial or societal context, regulated by mandatory external schedules, or complicated by innate circadian rhythms. Sleep duration pattern, perception of child overeating at 6 years, weight at 5 months, maternal smoking during pregnancy, and being a girl were each significantly correlated with being overweight/obese at 6 years of age (Touchette et al., 2008). Additionally, birth weight, parent's education, income, and ethnicity have been identified as complicating confounders in the relationship between a child’s healthy weight status and sleep (Carter, Taylor, Williams, & Taylor, 2011).

Sleep requirements vary for different age groups. According to the Center for Disease Control, children 5 to 10 years of age need ten to eleven hours of sleep per night. According to the 2004 National Sleep Foundation survey, *Sleep in America*, children are not getting enough sleep. The 2004 survey was the first nationwide appraisal of the sleeping habits of children and parents. The primary purpose of the poll was to describe children’s sleep habits and difficulties. The results revealed that school aged children (grades 1 to 5) averaged 9.5 hours of sleep per night when experts recommend 10-11 hours. Mindell (2005) affirmed that it is necessary to focus as much on the sleeping half of a child’s life as the waking half. Additionally, it was seen that children who secured fewer than recommended sleep hours have more difficulty not only falling asleep but take fewer naps during the day, and have more sleep problems overall

(Mindell, 2005). Recent studies have shown that not only do children (4-10 years of age) routinely sleep markedly less than recommended by current guidelines, but the high variance in night to night sleep duration appears to be associated with higher health risks (Spruyt, Molfese, & Gozal, 2011).

Although there is a range of advocated sleep times per age, there appears to be no precise number of sleep hour requirements that applies to all children. Recent studies reveal that there is a tremendous amount of variation between optimum hours of sleep needed per unique child (Iglowstein, Jenni, Molinari & Largo, 2003). Individual behavioral qualities and growth rates, distinct physical conditions and exclusive genetic make-up influence fundamental sleep necessities. Studies have also disclosed that sleep duration is influenced by an array of environmental factors that highlight and potentiate differences between and amongst communities (Owens, 2005). A recent rather controversial study proposes that the country of origin has significant effects on a child's parent-reported sleep durations (Hense et al., 2011). According to this research, these effects appear to overlay individual level predictors of sleep duration (Hense et al., 2011). Improved sleep measurement and enhanced understanding of cultural and biological influences on a child's sleep is an aspect of research that has been understudied.

The effect of sleep duration on diverse health outcomes seems undisputable. Adequate sleep is important for the growth and maturation of children. Insufficient sleep has been associated with an assortment of physical and psychosocial health deficits. Short sleep duration has been related to insulin resistance, larger waist circumference, decreased physical activity and television watching (Flint et al., 2007; Kuriyan, Bhat, Thomas, Vaz, & Kurpad, 2007; Wells et al., 2008). Concurrent with this decline in self-reported sleep durations is a worldwide increase in overweight and obesity with mounting evidence that sleep deprivation may be a risk factor for this increase in weight status in childhood (Nixon, et al., 2008). Overweight and obese children seem to have shorter and more disrupted sleep; children who slept eight to ten hours per night were 3.45 to 4.9 times more likely to be overweight when compared to children who slept more hours (Hart & Jelalian, 2008).

In addition to an increased risk of obesity, inadequate sleep has also been associated with impaired academic performance (Spiegel, et al., 2004; Wolfson & Carskadon, 2003). Increasing evidence indicates that sleep has beneficial effects on academic success. Short sleep duration was estimated to triple the risk of low performance on school entrance tests in young children (Touchette et al., 2007). Various study methodologies and assorted aspects of cognition, however, have rendered varying research results. Disagreement exists regarding the significance of the association between total IQ and sleep duration. Yet, several studies have verified a modest but chronic reduction of just one hour of nightly sleep in a cohort of preschool children was associated with decreases in the child’s cognitive performance at school entry (Gruber et al., 2010; Touchette et al., 2007).

Physical activity has been suggested to influence sleep duration, but no significant correlation has been found (Nixon, et al., 2008). Recent findings have not supported the common assumption that short sleep duration and obesity are mediated by physical activity (Ortega et al., 2011). Accordingly, the premise that individuals who sleep longer will spend more time in various physical activity intensities, can be fully explained by age or sexual maturation (Ortega et al., 2011). A lack of sleep is more likely to lead to overweight children than a poor diet or lethargic lifestyle through the assumed mechanism of metabolism and appetite hormone alterations (Carter, Taylor, Williams, & Taylor, 2011). Yet, in the past, low levels of physical activity have been linked to poor sleep quality (Gupta, Mueller, Chan, & Meininger, 2002). Additionally, there appears to be an additive interaction between short sleep duration and physical activity whereby children with low levels of activity and short sleep had 3.4 times higher odds ratio of obesity (Shi et al., 2010). The prevalence of obesity and decreased levels of physical activity parallel the prevalence of sleep deprivation (Vgontzas, 2008). Short sleep duration is associated with behaviors that are known to promote weight gain and obesity including lower physical activity (Stamatakis & Brownson, 2008).

Although the link between short sleep, physical activity, and weight status is consistently suggested in the literature, there is actually modest empirical data supporting a link between sleep duration and levels of activity. Available evidence on the relationships between sleep, levels of activity, and weight are based mainly on self-reported behaviors and diaries. Objective data is lacking. Current available literature is inconsistent and contradictory in youth (Gupta, Mueller, Chan, & Meininger, 2002; Van den Bulck, 2004; Wells et al., 2008). Use of accelerometers provides an opportunity to more accurately explore the relationships between weight status, sleep characteristics, and physical activity intensities.

For the purpose of health recommendations and outcome determinations, ‘poor sleep’ characteristics and parameters in children need to be identified. Possibly one of the best ways to establish adequacy in sleep characteristics is to understand its correlations with and implications on health psychosocial indicators. Sleep needs to be valued by family, school, and health care workers. Sleep is an important factor in the lives of children, yet all too often appears to be forgotten. Being tired is a diagnosable problem and should not be a part of a normal life (Wilson, 2005). The criteria to be used for recommended sleep guidelines for children need to be rendered from objective measurements and evidence-based practice if measurable interventions are to be employed.

The association between sleep characteristics and weight status, as explained by differences in physical activity dimensions, has not been adequately addressed in research (Hu, 2008). Sleep and physical activity have rarely been objectively monitored together in circadian activity configurations. The function of sleep as a daily contributor to the energy balance equation is rarely considered or quantified. The Heartfelt Study, however, did objectively monitor sleep and physical activity in adolescents over a brief twenty-four hour period only to corroborate that every hour of disturbed sleep was associated with a 3% decrease in daytime physical activity (Tremblay, Esliger, A., & Colley, 2007). Unfortunately, the short monitoring period of the Heartfelt Study (24 hours) limited the researchers' ability to analyze and correlate sleep characteristics and physical activity dimensions.

Best practice ought to consider objective quantification of the dimensions of sleep traits mandatory. Sleep characteristics are modifiable risk factors. It also appears to be necessary to disentangle what seems to be a triangular, complex problem between physical activity, sleep, and obesity. The integration of all the daily components of potential exposure to movement is essential. This makes intuitive the need to consider the configuration of activities over a twenty-four hour period.

Weight Status as a Health Indicator

Weight Measurement in Children

Obesity is described as excess body fatness and is fundamentally an imbalance between energy intake and energy expenditure (Daniels et al., 2005). The measurement of body fatness is complex and not typically possible in clinical or field settings. However, there are several methods available. Body Mass Index (BMI) is the most frequently used method. It is inexpensive and easy-to-perform for the screening of weight categories. Waist circumference is considered a method used for the evalution of visceral adipose tissue and correlates with high levels of plasma lipids in children, and as such is used as a predictor of cardiovascular disease risk factors in children (Savva et al., 2000). Since, skin fold measurements require implementation tools and training to perform, it is not used as frequently in the field.

Body Mass Index (BMI) is a number calculated from a child's weight and height. It is a reliable indicator and useful index for the evaluation of body fatness in children. BMI does not measure body fat directly, but research has shown that BMI correlates to direct measures of body fat, such as underwater weighing and dual energy x-ray absorptiometry (DXA) (Mei, Grummer-Strawn, Pietrobelli, Goulding, Goran, & Dietz, 2002). It is an indirect measure that correlates with direct measures such as dual-energy absorptiometry (DEXA) and underwater weighing (densitometry) (Rothman, 2008). Body mass index (BMI) formulas vary depending on the unit of measure. [Formula: weight (kg) / $[\text{height (m)}]^2$ or Formula: weight (lb) / $[\text{height (in)}]^2$ x 703] BMI has been widely recommended for pediatric use (Barlow & Dietz, 1998). BMI is plotted on a BMI-for-age growth charts (gender specific) to obtain a percentile ranking. Percentiles are the most commonly used indicator to assess the size and growth patterns of individual children in the United States. The percentile indicates the relative position of the child's BMI number among children of the same sex and age. The growth charts show the weight status categories used with children and teens (underweight, healthy weight, overweight, and obese).

A nationwide consensus statement prepared by professionals from an assortment of health care organizations described body mass index (BMI) as the best available clinical tool to not only screen for childhood obesity but also to monitor treatment progress (Barlow, 2007). BMI has been used since the 1990's as a simple, yet convenient, measure of overweight, obesity, and excess body fat. Two important factors speak to the rationale of this population wide measurement. First, the high reliability of measuring height and weight in various settings makes BMI a very practical method and assessment tool (Dietz & Bellizzi, 1999). Secondly, BMI has been shown to be a valid index of obesity and significantly correlates with laboratory measures of fatness in children (Pietrobelli et al., 1998). Additionally, in children, BMI-for-age references take into account the age of a child. This is crucial because a child's body build and body composition change with age (Must, 1991). Although BMI is unable to distinguish between fat mass and lean mass, it does correlate with more direct measures of fatness and is linked to health outcomes in children (Freedman, 1999; Pietrobelli, et al., 1998).

Despite the fact that in adults, BMI as a screening tool has historically shown low sensitivity and high specificity, there is no current evidence that BMI sensitivity or specificity differ significantly during childhood (Malina & Katzmarzyk, 1999). Body mass index (BMI), as a surrogate measure of adiposity, should be used as a growth monitoring tool in children. Despite the fact that this is a measure of relativity in weight rather than an absolute measure of adiposity, BMI is currently considered the preferred weight measure in children (Whitlock, Williams, Gold, Smith, & Shipman, 2005). BMI is clinically indicative of predictive weight status tracking from childhood to adulthood. The probability of adult obesity is ≥ 50% among preadolescent overweight children, according to their BMI (Whitlock, et al., 2005). Again, one of the most troublesome aspects of childhood obesity is the high occurence of tracking into adulthood and the established health risks that accompany the disease (Rowlands, Ingledew, & Eston, 2000).

Several studies have suggested an association and predictive ability between BMI rebound and weight status. BMI rebound is a term that refers to a period, usually between 4-7 years of age, when weight status, as measured by BMI, reaches a nadir and then proceeds to increase throughout adolescence and adulthood (Daniels, et al., 2005). Data is conflicting as to whether the BMI at the age of rebound is the important predictive determinant or if the age at which the rebound occurs is the mechanism to explain. Identification and clarification of this data could provide useful information in identifying children at risk before the development of obesity.

The early warnings for weight concerns in the United States were prompted in 1994 by the National Center for Health Statistics (NCHS) when the first three years of data collection from the National Health and Nutrition Examination Survey (NHANES) reported the statistically significant increase in obesity and overweight in adults (Kuczmarski, Flegal, Campbell, & Johnson, 1991). Since that time research has associated obesity and overweight in children with increased morbidity, mortality, and decreased life expectancy (Poirier et al., 2006). However, prior to the statistically revealing results of the NHANES, the emphasis of physical fitness and physical activity in youth had already begun to shift from a performance focus to a health focus (Malina, 2007). This modification was the consequence of an increasing concern and noted prevalence of fitness failures in youth. Changes in lifestyle associated with secular trends in less physical activity, more inactivity and increases in childhood overweight and obesity, have led to a complex, multifaceted health quandary. Physical activity could present as a consequence or an instigation of obesity. Lacking dose-response evidence between physical activity, weight status and health outcomes has impelled the solutions to be speckled in assumptions and subjectivity.

Lack of physical activity is hypothesized to be an important contributing factor in the development and preservation of childhood obesity (Hill, Wyatt, Reed, & Peters, 2003; Pratt, Macera, & Blanton, 1999; Rowlands, Eston, & Ingledew, 1999). Yet systematic evidence regarding the role of physical activity in weight loss treatments for children is limited (Goldberg & King, 2007). Recommendations are vague. The IASO (International Association for the Study of Obesity) states that children should incorporate both school and nonschool-based approaches, allot school time for physical activity, and include opportunities for noncompetitive sports (Saris, et al., 2003).

The ultimate goal of informing public policy as it relates specifically to health outcomes is contingent on the accurate assessment of the health indicators; physical activity dimensions, sleep characteristics, and weight status. The increased frequency of overweight and the persistence of childhood obesity highlight the public health importance of identifying correlates. The multifaceted influences and the domino effect of sleep, physical activity, and weight status track a lifetime of significant health implications in an individual. Without an objective assessment and evaluation of these correlates, the dose-response relationship is a supposition at best.

Academic Achievement and Academic Behavior as a Psychosocial Indicator

The health of a child has an effect on his or her ability to learn and to achieve academically. Regular school attendance is a necessary part of this learning process. Student absenteeism has a direct association with poor academic performance (Weismuller, Grasska, Alexander, White, & Kramer, 2007). Academic behavior as measured by attendance and cognitive function as measured by academic achievement are considered independent psychosocial indicators of a child’s health (Trudeau & Shephard, 2008). The term academic behavior in this case refers to the school attendance record of the student as maintained and submitted by the school administration. The attendance record reflects an accounting of times present for partial or entire school day class activities.

There have been, however, very few well-designed studies that have actually addressed the physical activity levels of elementary school children during a typical day (Dale, Corbin, & Dale, 2000; Stewart, Dennison, Kohl, & Doyle, 2004). Studies exploring the link between physical activity and academic achievement have for the most part included either subjective measures, categorical variables, or studied either very young children or older adolescents (Eveland-Sayers, Farley, Fuller, Morgan, & Caputo, 2009). Studies using self-reported physical activity have demonstrated conflicting results when examining academic performance (Coe, Pivarnik, Womack, Reeves, & Malina, 2006). Additionally, results are mixed among the studies that have studied the relationship between physical performance and activities and academic accomplishments. Discrepancies between research studies may be explained by differences in type, length and intensity of physical activity interventions, measurement methods of physical activity, study design (randomized versus non-randomized), and method of academic tracking (standardized testing versus individual scholastic grades).

Statement of the Problem

Gaps in the Literature

In summary, the lack of objective measurement of physical activity dimensions and sleep characteristics in children implicates not only the dose-response relationship but also the evaluation of the outcomes of such an association. There exists a preponderance of supposition research that bases its recommendations on self-reports. This method of data gathering in children has been shown to be inaccurate. Field studies that gather physical activity related to children from recall, proxy, or diary reports lack objective, comprehensively accurate data gathering techniques. Sleep assessments in children that are based on self- or parental- reports are a feeble base for evaluation and appraisal. The dimensions of physical activity and characteristics of sleep, both objectively measured, have not been the focus of a research study in a population of eight year olds. Furthermore, sleep characteristics and physical activity dimensions have not been viewed in a circadian configuration over an extended period of time (one week) with the intent and benefit of appreciating the significance of patterns of behavior and activity. The objective correlation of these variables will enable a dose-response that is tangible. A tangible dose-response will enable an enduring and accurate evaluation of a health outcome.

Within the past decade, the use of accelerometers has become the most acceptable objective measure of physical activity dimensions and sleep characteristics in children in naturalistic settings (Reilly, et al., 2008; Sadeh, & Acebo, 2002). The inaccuracy of self-reported physical activities were confirmed in a national survey through use of uniaxial accelerometers (Troiano, et al., 2008). The newly released triaxial accelerometers have increased capabilities. The enhanced and amplified potential of these monitors encourages the objective measure of physical activity dimensions and sleep characteristics in children (Ott, et al., 2000; Plasqui, et al., 2005). Analysis and correlation of these physical activity and sleep variables with a child's weight status and academic profile (achievement and behavior) will encourage an improved understanding of a dose-response health outcome.

The health outcome of weight status and the psychosocial outcomes of academic achievement and behavior as implicated by the dimensions of physical activity and the characteristics of sleep have not been verified through empirical research (Taras & Potts-Datema, 2005). The causality and direction, as well as the quantified measure of these variables, is lacking. The lack of clearly documented objective findings merely implies a relationship between academics and weight and physical activity and sleep rather than prescribe any specific, objectively obtained associations. Used as a basis for recommendations and guidelines, these relationships are vague, subjective, and do not speak to a dose-response relationship. Additionally, inadequate research exists regarding the specific effects of sleep deficiencies in children (Dahl, 1996). Sleep deprivation is known to impact learning and performance, however, sleep characteristics have not been objectively measured in children over a seven day period and correlated with reported standardized academic testings. Despite the importance of childhood sleep in cognitive development and growth, research is scant when exploring the issues of fragmented, inadequate sleep in children (Welsh, Pennington, & Groisser, 1991).

The distinct associations amongst the dimensions of physical activity and the characteristics of sleep have yet to be determined. It is the accuracy of these relationships that will make a difference in the health recommendations and ultimately in the health outcomes. Appreciation of the collaborative and synergistic mechanisms between these variables may impact our ability to better understand the corollaries, consequences, and effects of weight status and academic achievements in eight-year-olds. The implications for guidelines and recommendations are amplified as one begins to realize the impact of the reduction in physical education classes, absence of school recesses, lack of structure to after school programs, closed community centers, endorsement of walking school bus routes, distractions to sleep quantity and quality. Evaluating and objectively recording physical activity patterns among youth will encourage consensus related to recommendations and guidelines based on empirical evidence not subjective self-reports. This course of practice will assist in accurately informing health policy as the translation of this research will become markedly more precise.

Statement of Purpose

The purpose of this research was to determine the relationship among objective dimensions of physical activity and sleep and a health indicator (weight status) and two psychosocial indicators (academic achievement as measured by performance assessments [standardized testing scores and teacher evaluations] and the academic behavior of school attendance). The dimensions of free-living physical activity (intensity frequencies, durations, and ranges, as well as length and frequency of activity bouts) and sleep characteristics (sleep duration, number of wake episodes, and duration of wake episodes) were monitored in a cohort of eight year olds. The circadian activity-sleep count configurations were recorded through the use of the recently released triaxial ActiGraph accelerometer (GT3X, ActiGraph, Pensacola, Fl.). An ecological framework structured this study. The geographic environment included three campuses of two charter schools, in urban Detroit within a one mile radius of each other. The population of these elementary schools were socioeconomically, culturally, and racially comparable. The majority of students in both schools consisted of African American, low socioeconomic third graders.

Research Questions

The following research questions were addressed in this study:

1. What is the objective pattern of physical activity and sleep over the week in a cohort of eight year olds living in a low socioeconomic urban area?
2. What is the relationship between patterns of free-living (unstructured) physical activity dimensions and objective sleep characteristics in a cohort of eight-year-old children?
3. What is the relationship between patterns of free-living physical activity dimensions and the weight status as measured by body mass index (BMI) in a cohort of eight year old children?

4. What is the relationship between patterns of free-living physical activity and the psychosocial indicators of academic achievement and academic behavior in a cohort of eight-year-old children?
5. Are there differences in physical activity and sleep variables between those who passed and those who failed school reading and mathematics?
6. To what extent does a linear composite of sleep characteristics, weight status, academic achievement, and academic behavior have a relationship with a linear composite of physical activity in a cohort of eight-year-old children?

Significance to Nursing

Nursing may be stated as the science of human betterment. Research undertaken from a nursing perspective is challenged with the responsibility of putting the patient in the best condition for nature to act upon him/her (Nightingale, 1969). This philosophy has been restated and refined since 1859, but the essence is the same. To add to the significance of the science of nursing, it is imperative to bring research to the community. Accuracy of measurement is necessary to determine dose-response relationships to specify which aspect of physical activity is pertinent to a particular health outcome. The strength of the relationships between the health indicators of physical activity, weight status, and sleep vary considerably. The correlation and associations between the cited health indicators and the psychosocial indicators of academic achievement and academic behavior lack consistent methodological approaches, leading to irregularity in the strength of their relationships. The discrepancies are due in large part to the inconsistency surrounding the measurement and interpretation of these variables.

Although research continues to show the health benefits related to adequate physical activity and sleep requirements in children, current recommendations are not based on a substantial body of empirical evidence, but rather on a culmination of self-reports. The criteria required for recommended guidelines need to be rendered from objective measurements and evidence-based practice. If activity patterns and sleep characteristics are considered modifiable risk factors, best practice in nursing ought to consider objective quantification of these dimensions mandatory. The clinical nurse in a hospital, the school nurse, the nurse practitioner in a free-standing office or clinic is in a trusted position as informants and counselors of health advice and information. Collaborative efforts are most frequently negotiated by a nurse. The position, influence and responsibility of the nurse is progressively more instructional. A consensus in physical activity guidelines and recommendations through consistent methodologies, assessments, and interpretations will add to the evidence base and assist in the translation of research to policy.

Health Care and Society

Physical activity is known to provide numerous health benefits, particularly in reference to the prevention and treatment of certain chronic diseases (Hendelman, Miller, Baggett, Debold, & Freedson, 2000). Reduced physical activities combined with increased amounts of sedentary activities are major contributors to the body’s energy imbalance. This disequilibrium in energy is a significant factor in the worldwide increase in childhood obesity (Corder, Brage, & Ekelund, 2007). In addition, recent changes in lifestyle associated with secular trends in less physical activity, less sleep, and increases in childhood overweight and obesity, makes for a complex and multifaceted health quandary (Sturm, 2005). It is necessary to extricate this complex relationship amongst physical activity, sleep, academics, and obesity. An essential first step in this process is the integration of all the daily components of potential exposure to movement.

This makes intuitive the need to consider the configuration of physical activities over a twenty-four hour period.

The generous exacerbation in overweight and obesity status in children has occurred too rapidly to be attributed to anything other than a combination of environmental factors. To thoroughly address the research questions, a framework is needed that can implicate the reciprocity of multiple levels of considerations. The environmental influences on the behaviors of the children need to be separated into manageable components. The health and psychosocial indicators are distinct concepts that are ecologically correlated and mutually shared. The child's natural disposition and the environmental forces shape development to include health habits and outcomes. It is critical to examine the circumstantial relationships and precisely measure the dimensions and characteristics. The objective assessment of these traits will augment the accuracy of interventional maneuvers and proliferative health outcomes and vice versa.

In 1995, awareness was poignantly brought to the societal trends in weight status of U.S. youth (Troiano, Flegal, Kuczmarski, Campbell, & Johnson, 1995). Since that time many public health recommendations for youth have been published by various organizations. Although most include dimensions of physical activity (frequency, duration, and intensity), the guidelines differ markedly on prescriptive amounts. Frequencies range from three times a week to daily; intensities range from moderate to moderate-vigorous to vigorous; durations range from 20 minutes to 60 minutes often times depending on the intensities (NASPE, 2004; NIH, 1996; Pate, Trost, & Williams, 1998; USDA, 2000). Frequently used recommendations to accumulate 60 minutes of physical activity on all or most days are based on epidemiological associations between self-reported physical activity and health outcomes (Troiano, 2005). These national guidelines for children and adolescents speak to any kind of moderate-to-vigorous physical activity that increases heart rate and causes one to breathe heavily (Strong, et al., 2005). Objective measurement will add precision to the accuracy and recommendations.

CHAPTER TWO

Theoretical Framework

This chapter will present the theoretical framework used in this research. The study will be utilizing Bronfenbrenner’s Bioecological model. A detailed examination and evaluation of the model will be presented, as well as its particular applicability and usefulness in this type of study, population, and inquiry. Additionally, the parallel usage, similarities, and variations in the environmental domain often used in nursing theories will be discussed. The chapter will complete with an extensive review and critique of the literature.

Theoretical Framework with Worldview Perspective

A worldview is an encompassing and pervasive view that serves the basic function of facilitating our understanding of the world in which we live. Through constant clarification and justification, our integral sense of existence, our view of the world, is a dynamic, ongoing process. This personal view provides the mental lenses to support navigation through our surroundings. It can be considered a cognitive and perceptual map that aligns the basis for our belief system. A worldview is based on one’s sense of perceptions, experience, and learning. It serves to assist in providing a framework for one’s generation of knowledge as well as for the formulation of research-based ontological foundations. Worldviews have been equated with scientific paradigms, first popularized by Thomas Kuhn (Kuhn, 1970). A scientific paradigm is the intellectual perspective that guides the work of researchers. Without a scientific paradigm to direct, integrate and interpret inquiry, only random information is created.

Spontaneous, continuous, and ever-changing relationships and interactions of all living organisms with one another and with their environments are pivotal to understanding a person’s development. A person’s development is reflected in the joint function of their interrelationships and interactions with all living and non-living things as well as with their surroundings. The ecology of human development is the scientific study of this progressively mutual accommodation between an actively growing human being and the changing properties of the immediate setting in which the developing person lives (Bronfenbrenner, 1989). An ecological perspective is a conceptual framework which serves to direct attention to multiple levels of behavioral influence, to include individual and environmental determinants (Bronfenbrenner, 1979). Bronfenbrenner's unique definition of environment is novel in scope and meaning. One's perception of their environment, not necessarily its objective reality, is what really matters in development (Bronfenbrenner, 1979). Thus, to fully understand human growth and development, the entire ecological system in which an individual grows must be considered (Bronfenbrenner, 1994).

Ecological Models Discussed

The ecological paradigm was initially derived from a transformed and extended version of Kurt Lewin's classical formula: B=f (PE) [Behavior is a joint function of a person and environment.] (Lewin, 1935). Bronfenbrenner altered the equation slightly: D=f (PE) [Development is a joint function of person and environment.] (Bronfenbrenner, 1989). The distinction between behavior and development according to Bronfenbrenner is the dimension of time. Development is defined as the lasting change in the way in which a person perceives and deals with his environment (Bronfenbrenner, 1979). Developmental change is a process that occurs over intervals of time.

As a conceptual framework, the ecological theory is a comprehensive model for explaining human development. The basic principle of Urie Bronfenbrenner's ecological theory, the *Ecology of Human Development Theory*, originally proposed in 1979, states that development is influenced by experiences arising from broader social and cultural systems as well as by an individual's own immediate surroundings (Bronfenbrenner, 1994). *(Appendix A)* One of the strengths of this theory is that it portrays a comprehensive model of environmental influences on development and focuses on the changing relations between individuals and the environments in which they live. It includes both environmental and biological factors as contexts for the understanding of human development.

An ecological model identifies multiple levels of influence, causation, and potential interventions. This interdependence of levels provides researchers with novel points of intervention and evaluation. Relationships between individuals and their environments are viewed as mutually molding, acknowledging that individuals do not develop in isolation (Bronfenbrenner, 1979). No characteristic of the person exists or exerts influence on development in isolation. The ecological model acknowledges that a child affects and is affected by the settings in which he/she spends time. Everything in a child and a child's environment affects how a child grows and develops. A person is synergistically and bidirectionally influenced by their relationships. Development takes place over extended periods of time through processes of progressively more complex, fairly regular interactions between a child and the persons, objects, and symbols in its immediate environment. The ramifications related to the interconnecting environmental influences are distinctly enumerated in this framework. Bronfenbrenner proposed an ecological perspective that directed attention to behavioral, individual, and environmental determinants (Bronfenbrenner, 1979). This multilevel ecological model implies a reciprocal causation between the individual and the environment (McLeroy, Bibeau, Steckler, & Glanz, 1988). The interactions between the environment and the person encourage the development of an individual's lifestyle. Bronfenbrenner's theory illustrates the bidirectional interaction of a child's biological disposition and the environmental forces that shape development (Rimm-Kaufman & Pianta, 2000). This theory exemplifies the interface between a child, family, home, school, peer group, and neighborhood to create a dynamic network of relationships. These interactions form patterns and relationships that can be described not only as influences on a child's development but also as outcomes in their own right. Consequently, the modifications of contextual relationships over time explicate factors in an individual's development.

Environment is defined as the conditions, circumstances, and factors affecting an individual, family, and community (Laustsen, 2006). Ecological models have been described as typologies of individual, social, and environmental features (Sallis & Owen, 1997). One's environment is the space or setting outside the individual. Environment, as it pertains to the behavior and development of an individual, is viewed as the perception of a setting rather than the static existence of an objective reality (Bronfenbrenner, 1979). Ecological refers to a person or persons' transactions with their physical and sociocultural environments (Sallis & Gwen, 1996). Putting this in the context of health and psychosocial indicators, although a child's genetic make-up may very well load the obesity gun, the environment undoubtedly pulls the trigger (Ells et al., 2005). This assertion emphasizes quite graphically the essential relationship of the environment on the development of an individual's physical and psychosocial make up. Researchers and practitioners alike have acknowledged an essential need to develop ecological strategies the include influences beyond the individual (Green, Richard, & Potvin, 1996). Social and physical environments directly affect a person's state of health; the *who* you are is unequivocally affected by the *where* you are (Macintyre & Ellaway, 2003). There is developing consensus that the environment, rather than biology, is driving many health concerns, particularly the obesity epidemic (Hill, Wyatt, Reed, & Peters, 2003). It has been argued that the context of the environment may contribute more than the characteristics of the person (Barker, 1968). These affirmations give credence to the importance of the environment upon the development of our physical and psychosocial health.

Environments may influence individuals explicitly or implicitly. Their effects may be intentional or unintentional. Although an ecological perspective provides a comprehensive view of health, it does not provide a parsimonious set of predictabilities related to health phenomena (Grzywacz & Fuqua, 2000). Descriptions, clarifications, and delineations of how the environment affects particular health indicators are challenging secondary to the complicated nature of the multilevel, multifactorial interactions of these relationships.

The ecological theory draws attention to more specific aspects of a complex environment by disaggregating it into a set of interacting systems (Bronfenbrenner, 1979). These interactions affect individual as well as community consequences and improvements. Ecological models theorize that components and settings are interdependent and yet can exert bidirectional effects on each other. As a result, there is always an interplay between the psychological characteristics of a person and their specific environment; one cannot be defined without reference to the other (Bronfenbrenner, 1989).

The benefit of the ecological approach is appreciated not only as a model for interpreting behavioral patterns, a preliminary for determining and testing interventions, but also as a framework for identifying appropriate related variables. Context specific behavioral measures include specific environmental correlates to attain specific health behavior outcomes. In other words, individuals not only behave differently in different settings but various settings will impact behavioral reactions and activities differently. Thus, the interdependence among individuals, their behaviors and health outcomes, and their environments can best be appreciated through an ecological model. It is the logical framework for the best appreciation of the health and psychosocial correlates in the settings of this research population.

Bioecological Model Discussed

The dynamic elements of development have been further differentiated and classified by Bronfenbrenner in his more recent conceptual expansion of the bioecological framework to include an individual's biopsychological characteristics (Bronfenbrenner, 2005). In this more developed perspective, biology (such as a genetic makeup) is as significant as the environmental developmental contexts (Bronfenbrenner & Ceci, 1994). The *Bioecological Theory of Human Development* is an evolving theoretical system that establishes the importance of bioecological levels on human development. *(Appendix B)* Within this theory, human development is defined as a phenomenon of continuity and change in the biopsychological characteristics of human beings (Bronfenbrenner, 2005). Human biology is intimately integrated with various environmental platforms bringing the features and characteristics of the developing person into the bioecological system. Developmental processes are profoundly affected by events and conditions in the larger environment and reciprocally accords major importance to the influence and nature of the environment.

Bioecological models of health behavior focus on individual influences as well as on social and environmental factors that may facilitate or inhibit individual behavior (Sallis & Owen, 1997). Bioecological models can elaborate on the continuum of behaviors by promoting certain actions and by discouraging others, implying that an environment or a setting could add explanatory value above and beyond the interpersonal and intrapersonal variables. In public health, bioecological models refer to a person's interactions with their physical and sociocultural surroundings and focus attention on both the individual and the environmental factors as targets for health promotion interventions.

The bioecological environment is depicted as a set of nested structures, concentric circles, with the individual located in the smallest circle in the center. Bronfenbrenner described these structures as interconnected systems in an attempt to augment their useful application in expanded bioecological theory foundation (Bronfenbrenner, 2005). The five basic levels of the bioecological model describes a dynamic system across space and time (Bronfenbrenner, 2005):

Table 2.1 Five Levels of Bioecological Model

Microsystem	The innermost level, the immediate setting within which individuals interact, is the primary setting that surrounds an individual. It speaks to interpersonal interactions in specific settings. The microsystem is a pattern of activities, roles and interpersonal relations experienced by a developing person in a given face-to-face setting (Bronfenbrenner, 1989). The microsystem consists of anyone in a close relationship for a substantial amount of time with the individual. Persons in this level have the most immediate effect on the individual. The microsystem modifies and alters over time to include and exclude contacts and interactions as an individual grows, matures, and advances through life. It is likely that more than one microsystem plays a role in understanding physical activity dimensions and sleep characteristics in children.
Mesosystem	This is a system of microsystems, two or more settings involving the individual and interacting with various venues (Bronfenbrenner, 1989). This level accommodates the associations and processes that transpire between two or more settings that embrace the maturing individual. The mesosystem also includes and implicates the alliances, linkages, and processes between these settings and surroundings in an individual's microsystems. It is not just the presence of a particular setting or element of the environment that is importance, but the quality of the interaction that takes place within and between surroundings. This level impacts and adds significantly to promoting the development of an individual (Berk, 2000).
Exosystem	This system is a larger social system and surrounds the mesosystem. It is composed of the linkages and processes between two or more microsystems and refers to social settings that affect the person but do not ordinarily include the person (Bronfenbrenner, 1989). Although the exosystem level may not directly cross the path of the individual, it inevitably has an enormous yet subtle effect on a person.
Macrosystem	This outermost layer overarches and engulfs the microsystem, mesosystem and exosystem (Bronfenbrenner, 1989). The macrosystem consists of entities that influence, and sometimes support, an individual within an environment, such as cultures, norms, resources, belief systems, and laws.
Chronosystem	This system encompasses the dimension of time; elements in this system can be either internal or external to an individual (Bronfenbrenner, 1989). Changes accounted for by this system relate to the constancy and change not only in the person but also in the environment. Particular attention is focused on developmental changes triggered by life events or experiences. The critical feature of such events is that they alter the existing relation between person and environment.

The bioecological system considers the combination of an individual's natural disposition and environmental forces coming together to shape the person's development. The status of health outcomes is the result of initiatives and habits acquired throughout the process of growth and maturity. This development occurs simultaneously while an individual transitions through time and is influenced by this multilevel system. This is an evolving interaction through which the behavior of an individual is cultivated and expanded (Bronfenbrenner, 1979). In this framework, human development is conceptualized from an interactive, bidirectional, contextual perspective. Development and progression cannot be effectively or accurately explained without consideration of the context, the bioecological niche, in which the individual is rooted (Davison & Birch, 2001). Development is further defined as a lasting change, a process over time, in which a person perceives and deals with this environment (Bronfenbrenner, 1979).

There are several defining foundational properties in Bronfenbrenner's *Bioecological Theory of Human Development* that illuminate the functional relationship between the environment and the characteristics of the developing person. These properties advocate for interactive relationships between the individual and environment and speak directly to the research at hand. These include assumptions, concepts and propositions that succinctly contribute to the systematic understanding of the processes and outcomes in the bioecological model.

There is one basic *assumption* of the bioecological model to introduce the applicability to this research (Bubolz & Sontag, 1993):

Basic assumption	An individual is influenced by both biological and cultural factors and development depends on other human beings.

There is one basic *concept* of the bioecological model to further advocate for the suitability to this research (Bronfenbrenner, 1979; Bubolz & Sontag, 1993):

Basic concept	Human development is defined as a continuous process of an individual actively interacting with their environment. As a person grows, it is expected that they will be able to navigate with increasing complexity through their environment.

The three *propositions* of the bioecological paradigm that help to explain the basic relational dynamics and interactions in this ecosystem and how these processes affect the developmental outcomes include (Bronfenbrenner, 2005):

Table 2.2 Three Propositions of the Bioecological Model

Proposition I	Experience is a critical element in defining the bioecological model. The term is used to indicate that the scientifically relevant features of any environment for human development include not only its objective properties but also the way in which these properties are subjectively experienced by the persons living in that environment. This emphasizes the importance of understanding the nature of objective forces, phenomenological or experiential, in development.
Proposition II	Human development takes place through processes of progressively more complex reciprocal interaction between an active, evolving biopsychological human organism and the persons, objects, and symbols in its immediate external environment. To be effective, the interaction must occur on a fairly regular basis over extended periods of time. Such enduring forms of interaction in the immediate environment are referred to as proximal processes. • Proximal processes are posited as the primary engines of development.
Proposition III	The form, power, content, and direction of the proximal processes producing development vary systematically as a joint function of the characteristics of the developing person (including genetic inheritance); of the environment (both immediate and more remote) in which the processes are taking place; of the nature of the developmental outcomes under consideration; and of the continuities and changes occurring in the environment over time, through the life course, and during the historical period in which the person has lived. • For development to occur, the person must engage in an activity. • The activity must take place on a fairly regular basis, over an extended period of time. • The activity must take place long enough to become increasingly more complex. • Developmentally effective proximal processes are not unidirectional. • Proximal processes are not limited to interpersonal interaction; they can also involve interaction with objects and symbols.

Propositions II and III are theoretically interdependent and subject to empirical testing.

In the bioecological model, the characteristics of the person function both as an indirect producer and as a product of development (Lerner, 1982). According to these propositions, development is a relational process requiring the bidirectional linkage of the individual with the physical and social environment (Lerner, 1995). A bidirectional linkage is one in which the person and the environment simultaneously and mutually influence each other. An operational research design that permits this concurrent developmental investigation is referred to as a *Process-Person-Context-Time Model (PPCT)* (Bronfenbrenner, 2005). The PPCT model is a research designed approach for discovery that directs the investigation of the bioecological model propositions. As the biological model is attentive to process, person, context, and time variables, it seems apparent that this framework would be applicable to any life experience that occurs throughout human development. These four interrelated constructs of Bronfenbrenner's bioecological model allow for analysis of variations in developmental processes and outcomes as a joint function of the characteristics of the environment and the person (Bronfenbrenner, 2005):

Table 2.3 Process-Person-Context-Time (PPCT) Model

Process	• Developmental component
	• Involves the fused and dynamic relation of the individual and the context
	• Encompasses particular forms of interaction between the person and the environment
	  ○ Proximal processes are primary mechanisms producing human development over time
	  ○ Effects vary by person, context, and time

Person	• Individual repertoire of biological, cognitive, emotional, and behavioral characteristics developing over time
	  ○ Dispositions that initiate and sustain proximal processes
	  ○ Bioecological resources needed for functioning of process at given stage
	  ○ Demand characteristics that foster or disrupt the operation of proximal processes / elicit positive or negative reactions from others

Context	Conceptualized as the nested levels or systems of the ecology of human development
	  ○ Microsystem
	  ○ Mesosystem
	  ○ Exosystem
	  ○ Macrosystem

Time	• Conceptualized as involving the multiple dimensions of temporality • Moderates changes across the life course: explains change over time from the cumulative effect of individual choices ○ Chronosystem

The first of these constituents and the core of the bioecological model is process. This construct encompasses particular forms of interaction between person and environment. Proximal processes operate over time and are posited as the primary mechanisms producing human development. The effects of proximal processes are more powerful than those of the environmental contexts in which they occur (Bronfenbrenner, 2005). The changing person and their surroundings compose the basic processes of development. The power of such processes to influence development is presumed and shown to vary substantially as a function of the characteristics of the developing person, of the immediate and remote environmental contexts, and of the time periods in which the proximal processes take place. In bioecological research, the principal main effects (outcomes) are likely to be interactions (Bronfenbrenner, 1979).

A research paradigm that analyzes the synergistic interaction between one's biological assets and one's environmental settings assures a comprehensive worldview. The bioecological model rests on an adaptive view of human beings in continuous interaction with others and with their environment. Synergism is used to describe an experience in which the joint operation of two or more dynamisms produces an effect that is greater than the sum of the individual effects. Synergy is produced by the combined effects of two or more elements- environments-dimensions-characteristics that would otherwise by unattainable alone. Synergy is born out of a good fit between the individual and the environment (Kelly, 1990). Synergy occurs when an individual actively interacts with their environment to ensure a goodness-of-fit (Germain & Gitterman, 1980). A good fit refers to a matching of individual qualities with environmental characteristics to produce positive human health behaviour, for example, one that may be conducive and supportive to increased physical activity or sleep quality. Once established, one attains a level of homeostasis / equilibrium. The bioecological model illustrates the development and assessment of an individual synergistically at various levels. Every human quality is inextricably embedded, and finds both its meaning and fullest expression, in particular environmental settings.

Comparison of Nursing Environment Domain and Bioecological Framework

The similarity of the four concepts of the nursing metaparadigm and the above cited PPCT The comparisons between the nursing concepts and the bioecological framework are intriguing to consider.

Table 2.4 Comparison of Nursing Concepts and PPCT Model

Nursing Concepts (Fawcett, 2005)	PPCT (Bronfenbrenner, 2005)
Health: human processes of living and dying	**Process**: interaction of person and environment
Human beings: individuals or aggregates who participate in nursing	**Person**: personal attributes and characteristics
Environment: human beings, significant others, and physical surroundings	**Context**: environment to include persons, objects, symbols
Nursing: actions taken by nurses on behalf of on in conjunction with human beings and goals/outcomes of actions	**Time**: continuous and changing dynamic

The understanding of the bioecological model addresses the nursing affirmation and challenge related to the interaction an individual has with their environment and surroundings (Nightingale, 1969). Yet, current epistemological foundations of nursing theory incorporate only minimal bioecological modeling (Laustsen, 2006). The term environment in nursing theory literature usually implores a static entity and rarely alludes to the significance of a dynamic relationship within a setting. The extension of the environment through the concept of ecosystems will include the practice behaviors of health care systems and public health laws. The relationship and interface of persons with their surroundings is frequently presented linearly in many of the nursing theories. Within the bioecological model, the dynamic interaction and relational nature of persons and their environments is addressed extensively and bidirectionally. Within most models, nursing theories support a consistent cognizance of the domain of environment. Ecology is bound by action and reaction, reciprocal effects, influence and causation, and a web of interrelationships. The perceived restrictive nature of the nursing environment domain does not inform the nursing paradigm in a substantive manner (Chopoorian, 1986).

Table 2.5 Definitions of Environment from Nursing Theories

Definitions of Environment The concept of **environment** has been accorded a plethora of meanings in nursing theories.	
Florence Nightingale (1859)	• Anything that can be manipulated to place a patient in the best possible condition for the actions of nature • All the external conditions and forces that influence the life and development of an organism • Optimize environment to promote healing and optimal health
Jean Watson (1979)	• Encompasses social, cultural, and spiritual aspects of society • Provides values, goal settings, and behavior determinates
Martha Rodgers (1970)	• Open system • Considered to be all that is external to unitary man • Specific environmental (energy) field exists for each human field • Infinite environmental change that is continuous and inseparable from human • Changes in human is integral and simultaneous to changes in environment
Sister Callista Roy (1976)	• All conditions, circumstances, and influences surrounding and affecting the development and behavior of a person • Internal and external environments provide input in the form of stimuli • Continuous change and interaction with the person
Betty Neuman (1972)	• Internal and external forces surrounding the person at any given time • System stability affected by intrapersonal, interpersonal, and extrapersonal stressors interfering with line of defense
Rosemary Rizzo Parse (1981)	• Universe; everything in the person and their experiences • Constant interchanges energy with the human • Inseparable from and evolving with the human

(Wesley, 1994)

Environment is a concept central to the nursing domain. To the above cited theorists, environment encompasses energy fields, social systems, family, society, culture, the patient's room, the nurse, and all that surrounds a person. The current concept of environment in nursing, however, is vague and transient and lacks consistency in nursing epistemology. Although nurses have historically included the concept of a dynamic environment within the domain of nursing's discipline, the significance of biotic and abiotic interrelationship in a more global venue has eluded them. Fawcett, with a simultaneity foundation in her *Reciprocal Interaction World View*, comes closest to describing the rhythmical interchange of humans with their environment (Fawcett, 2005). The scope of influence, however, is limited in its proximity to the human and does not consider the interactions amongst abiotic or nonphysical aspects of the environment.

The absence of physical factors (climate) and nonphysical factors (economics, beliefs, law, and politics) have been detrimental to the circularity of influence and causation. Centrally developed environmental nursing theories that describe only environmental properties, components, and dimensions are inadequate to maintain or change health care outcomes. Missing is the effective inclusion of local and global societal mechanisms that interact to maintain healthy settings and explain health care policies (Meleis, 2005).

Bioecological Framework Applied

A conceptual models approach to physical activity using a bioecological approach was first described around the turn of the century (Dzewaltowski, 1997; Sallis & Owen, 1997). With the realization that most adults in industrial countries do not meet physical activity guidelines, researchers sought to implement population-wide mechanisms for assessment and interventions. The bioecological model posed to have the most potential to systematically assess the methods and levels of influence on community behaviors (Bauman, Sallis, Dzewaltowski, & Owen, 2002; Sallis, A. Bauman, & M. Pratt, 1998). Continued research has demonstrated the viability and suitability of bioecological models related to multilevel physical activity interventions, targeting social environments, physical environments, and policy modifications in large populations (Sallis et al., 2006). A heuristic model (*Youth Physical Activity Promotion Model*) was also adapted for bridging the gap between bioecological theory and practice (Welk, 1999). It was couched within a social bioecological framework and the Precede-Proceed Model and served as a guide for physical activity promotion, using intra- and extra- individual features (McLeroy, et al., 1988). Additionally, the bioecological model was distinguished as a valuable tool to study complex community problems by allowing researchers to divide a multifaceted question about health disparities into manageable components (Reifsnider, Gallagher, & Forgione, 2005).

Bronfenbrenner’s bioecological model has also been utilized to guide qualitative research (Matheson & Achterberg, 2001). The activities, roles, and interpersonal relations that transpired as students simultaneously interacted with each other and with a computer-based instruction were observed and analyzed. For the purpose of describing the student-computer interaction, themes were categorized as students completed a nutrition computer-assisted instruction program. The setting was measured to be bioecologically valid and to ensure that the interactions were genuine and uncontrolled. The grounded theory analysis developed in this research provided a framework to explicate the differences and the similarities between children as they worked together on this teaching program.

The purpose of a bioecological framework is to focus awareness on the environmental causes and implications of specific behaviors in an effort to assist with relevant and explicit interventions to improve health outcomes (McLeroy, et al., 1988). A bioecological framework can be used to examine the environmental interactions that influence the behaviors related to childhood activity, to include family, school and community risk factors and their reciprocal interactions (Davison & Birch, 2001). Youth physical activity is a complex behavior that is persuaded and impressed by many factors. A child’s activity patterns are shaped by a composite of biological characteristics, parental influences and social consequences. These are in turn shaped by broader contextual factors such as the availability of recreational facilities, the structure or lack of structure of school physical education programs and recess allotments, and neighborhoods’ safety issues. The associations and relationships of these considerations can be dismantled and scrutinized in a bioecological model. The summation of the effects will be best appreciated when the factors and levels are examined critically. The implication is that interventions must target changes in variables from all categories to achieve substantial and lasting behavioral changes and beneficial health outcomes. Bioecological models are unique in their explicit inclusion of environmental variables that are expected to influence behavior (Sallis et al., 2006).

There is nascent evidence that multilevel bioecological approaches may indeed be essential to bring about population improvements in health (Economos et al., 2001). Research to date supports the assumption that there are multiple levels of influence on physical activity (Sallis, et al., 2006). The ability to operationalize a bioecological framework for the benefit of health behavior changes and for the evaluation of the effectiveness of such manipulations, however, is a challenge. Bioecological models are characterized by their explicit inclusion of environmental variables that are expected to influence behavior and interactions within physical and sociocultural surroundings (Sallis, et al., 2006). The specifically objective dimensions of physical activity, the characteristics of sleep, and the weight status of the individual nested in the microsystem will assist in adding clarity to the dissemination of these influences through the corresponding levels. To examine the bioecological and contextual relationships, it is critical that the elements of the interactions be precisely measured. The objective assessment of a dimension or characteristic of an individual will have a ripple effect concentrically to other aspects of their environment and vice versa. The introduction of an objective and accurate account of physical activity coupled with sleep will ultimately lead to more effective health recommendations, guidelines, and interventions.

The relative consistency of the relationship between physical activity and weight status is surprising considering the lack of validity and reliability noted in measures assessing physical activity among children (Sallis & Saelens, 2000). The interactions between environmental factors and biological variables explain most of the inter-individual variations at the level of physical activity (Sallis et al., 2003). The effectiveness of interventions as represented by a bioecological system is contingent on the accuracy of the measurement. Consequently the relative importance of contextual and composite relationships associated with physical activity in a child’s life may very well be underestimated.

Environmental factors that generally modify the energy expenditure for physical activity include community environment, transport automation, school funding, physical education policies, socio-economic status, and family habits. In particular and specific to this research, the family and school atmosphere modify and moderate a child’s activity behavior. Contingent on the disposition of the child, the interaction and interface with the environment will manifest itself on the development and health outcomes of the child. Physical activity intercessions, such as outdoor play and school activities, are unlikely to succeed without alterations in the family and school environments in which a child lives. Current environmental conditions appear to endorse an inactive lifestyle that is likely to contribute to a sedentary predisposition and positive energy balance. Some researchers have even postured that indeed the environment in the United States encourages the consumption of energy and discourages expenditure of energy (French, Story, & Jeffery, 2001). Health consequences of this type of existence include a preponderance of resulting childhood obesity.

The rising prevalence of obesity has been attributed in part to population-level changes in physical activity. The assertion is that there is a secular decline in physical activity levels and that low levels of physical activity are associated with weight gain (Wareham, van Sluijs, Ekelund, 2005). This bioecological transition to a more inactive population appears to be occurring simultaneously with an increase in obesity (Ham, Macera, Jones, Ainsworth, & Turczyn, 2004). Also coinciding with the increase in pediatric overweight over the past two to three decades is a decline in children's sleep duration (Iglowstein, Jenni, Molinari, & Largo, 2003). Since physical activity is multi-dimensional and difficult to assess, research has as yet been unable to provide any consistently reliable causal inference to the dimensions of physical activity, the characteristics of sleep, and the weight status in children.

Much of the data on physical activity measures is gathered as proxy domain-specific measures. In other words, it is inferred that physical activity in this country has declined based on such factors as an increase in second car ownerships, labor-saving devices in the home, time spent viewing television, a decline in active transportation for children, and a decline in physically-demanding occupations in this country. Recently, however, results from the National Center for Educational Statistics' Early Childhood Longitudinal Study indicated that the weight of students, as well as the opportunity for physical activity within the school day, affected the students' performance in both reading and mathematics achievement (Byrd, 2007). Most of the research in the area of insufficient sleep in children has been based on survey studies with limited empirical data on factors that may potentially confound the associations (Levers-Landis, Storfer-Isser, Rosen, Johnson, & Redline, 2008). No population-level data on temporal trends in total circadian activity are available.

The challenge of these considerations is clearly illustrated in the areas of physical activity, sleep, weight status, and academics. Multilevel approaches to research are more effective, powerful and sustainable than single-level approaches (Sallis, et al., 2006). Despite an extensive array of studies, the full impact of the benefits of physical activity is not well understood. Additionally, the consequences of secular trends in sedentary activity or sleep are also not well comprehended. Consequently, the individual interventions attempted thus far have not produced long-term effects (Sallis & Owens, 1999). Individually based approaches to obesity prevention and treatment are widely viewed as ineffective by themselves (Smedley & Syme, 2000). Exclusively personal attempts to address this epidemic do nothing to alter the environmental factors believed to contribute to the population wide problem of inadequate physical activity. Cross-sectional data does indicate, however, that environmental variables are associated with physical activity behaviors (Sallis, Bauman, & Pratt, 1998).

The environment which an individual grows up in and interacts with will impact the behavior of that person. Interventions that span the bioecological levels of an individual's environment may provide more encouraging and optimistic results. Working within a bioecological model requires the assessment, evaluation, and measurement of multiple intervening levels of influence within, between, and external to an individual (Spence & Lee, 2003). Specific objectively measured health indicators (physical activity dimensions, sleep characteristics, and weight status) at various bioecological levels will add to the precision of assessing, analyzing, and constructing guidelines, recommendations, and health outcomes. Consensus seems to be emerging that multilevel approaches based on bioecological models hold promising approaches in health research, disease prevention, and health promotion efforts (Smedley & Syme, 2000). Improved bioecological models will lead to a better understanding of the multiple levels of factors that synergistically influence health behaviors. Bioecological models are a more productive framework for physical activity promotion and analysis due to their orientation with an individual's physical and sociocultural surroundings (Sallis, et al., 2006).

The proliferating rate of chronic health implications in children as a product of the escalating pace of obesity underscores the importance of understanding the individual and environmental involvements. An analysis of secular and social trends that resonate across settings could enhance a paradigm shift in attitudes, regulations, and proposals. Obesity is not solely a matter of personal responsibility but a collective responsibility and should be assessed as such. Framing the health of a child bioecologically can lead to an enlightened consensus in objectives and interventions. Given the assumption that both nature and nurture affect the health of a child, interpersonal (microsystem) and community (mesosystem) bioecological levels will be the focus in this research. This study will concentrate on the first two levels of the bioecological framework.

The eight-year-old child is nested in his/her immediate environment, the microsystem. This explicitly involves the family composition. Specific focus will be on three methodically measured individual biological health indicator variables. The physical activity dimensions, sleep characteristics, and weight status measurements will encourage the detailed tracking of these behaviors. The interactions within one's immediate family impacts subtle aspects of their behaviors and health outcomes. The responses from the demographic questionnaire will supplement the data from the motion sensors. The household routines will be correlated to the objectively measured health indicators. The bioecological framework will assist in the clarity of the mutual influences from this level on the studied behaviors. The behavior of an individual is influenced by interactions with his/her ecologies.

The linkages between the various levels of the environment affect the degree of physical activity and the characteristics of sleep in one's life. A bioecological perspective considers the contextual effect on the composition and the behavior of an individual. Multiple levels of influence on an individual, such as family, school, community, can simultaneously impact choices of behavior, such as physical activity or sleeping conditions. Environmental factors are often behavior specific. The more proximal the dimension is to the individual; the more influential it will be to immediate behavior (Bronfenbrenner, 1999).

The measured psychosocial indicators related to academic achievement and behavior will be considered in the school setting, at the concentric level of the community. The circumstances of the family climate and the individual health indicator characteristics will reciprocally affect the school functions, academically and attendance based. The objective measurement of academic performance through standardized testing and the more subjective grading of the classroom teachers will be impacted in the school setting by the family composition and home environment, as well as the individual health indicators of the child. This system ascribes to the interrelations among the various settings in which an individual is involved. The family dynamics and the school atmosphere reciprocally incite the behavior of the individual, specifically the objectively monitored circadian configuration of activity and sleep.

Research related to specific health indicators has in the past generally focused primarily on explicit characteristics and has not considered the family system or the multileveled context from which a child emerges (Bronfenbrenner, 1994). A broader contextual approach using a bioecological framework, in combination with objectively measured physical activity dimensions and sleep characteristics, will add to the explicit implications related to the recommendations and detailed guidelines that contribute to improved health status. The accurate assessment of our physical and psychosocial health is related not only to a number of individual health outcomes but it is also an important aspect to public health surveillance (Ham, et al., 2004). For this reason, the objective measures of physical activity dimensions and sleep characteristics are imperative. The amount, type, and frequency of physical activity, as well as the characteristics of their sleep quality, as experienced by eight-year-old children, are influenced not only by their biological composition but also by their relationship to their environment and to one another. The reciprocal exchange of the influences among levels of the bioecological framework confirms the appropriateness and logic of this worldview for this research.

Research Framework and Bioecological Framework

The multiple interrelationships of the study variables are diagrammatically illustrated in the research framework. (*Appendix C*) The health indicators and the psychosocial indicators are distinct concepts yet interrelated, ecologically. The health indicators in this study were individual characteristics used to describe aspects of the children's health. Elements of the energy expenditure segment of the energy balance equation were targeted and objectively measured for these qualities. The energy cost of physical activity, the energy restorative phase of sleep and the measured body mass index were constructs developed to define the concept of health indicators. The psychosocial indicators pertained to the influence of social factors on the child's behavior. The school environment was the focus of these accomplishments. Academic achievement and academic behavior were constructs used to index the psychosocial concept and as such added measurable specificity to the concept of psychosocial indicator. A proposition statement describes the relationship between these variables. Distinct properties of the Bioecological model define this interactive perspective and the relationship of the concepts and constructs with each other. According to the Bioecological model, the objective properties and the subjective experiences of the health and psychosocial indicators define experience. The relationship between the health and psychosocial indicators is exemplified by multi-directional forces, phenomenological and experiential. The former depicts the nature in which the environment is perceived and changed by the child. The experience pertains to the realm of subjective feelings harbored by the child, to include likes/dislikes, hopes, doubts, and beliefs.

Both subjective and objective forces exert a strong force on development during the formative years. The regularity and proximity of interactions in a child's life vary systematically and consequently impact their development and their health.

The relationships among the constructs are theoretically interdependent and subject to empirical testing. The relationships and associations between the quantifiable dimensions of physical activity, sleep traits, weight status, academic behavior, and academic achievement were the focus of this research. The ecological niche in this study focused on the family and school setting and was impacted by the community in general. Environments directly affect health. The delineation of how the environment affects health is challenging because of the multi-level, multi-factorial, and multi-structural nature of the influences. The reactions to the environment were assessed in the two arenas of health and psychosocial indictors. The effects of the environment may directly impact developmental behavior, situational settings may alter health behaviors, or unspecified mediating variables may alter the response to the environment. The determination of a correlation between and/or amongst the variables will enable a more precise health promoting intervention, implementation and evaluation.

The health indicators of physical activity dimensions, weight status, and sleep characteristics were objectively determined. Physical activity was measured by accelerometry in three capacities; energy expenditure, intensity ranges, and bouts of moderate-vigorous activity. Step counts and activity index (vector magnitude: square root of the sum of the squares of all three axes) served as the accepted proxy for energy expenditure. Frequency and duration of daily intensity ranges as well as number and frequency of cut-point specific moderate-vigorous activity bouts for eight year olds were also counted through triaxial accelerometry. Weight status was calculated for age-specific BMI through use of a digital scale and stadiometer. Sleep was recorded on the accelerometer for duration as well as frequency and length of arousal/wake episodes per night. The psychosocial indicators selected included academic achievement and academic behavior. Performance assessment of academic achievement was collected on two levels, subjective teacher grades and evaluations and standardized yearly state-wide tests. Academic behavior was identified as the attendance school record. The links and the affiliations in the diagram depict the correlational nature of the relationships.

Review of Literature

Obesity /overweight has been acknowledged to be an epidemic and a public health crisis among children internationally (Lobstein, et al., 2004). The Centers for Disease Control and Prevention (CDC) has reported a quadrupling in the rise of childhood obesity (6-11 year olds) over the past 20 years (Centers of Disease Control and Prevention & Statistics, 2003). In addition, approximately 50% of children appear to have 'obesity susceptibility genes' on which environmental changes have acted over the past 25 years (Barlow & Dietz, 1998; Daniels, et al., 2005; Koplan & Dietz, 1999). The generous exacerbation in obesity and overweight in children has occurred too quickly to be attributed to anything other than a combination of environmental factors. Yet despite the marked implications of environmental influences on weight status, there is a dearth of good information available on national trends in youth physical activity or fitness levels (Pratt, et al., 1999).

Physical Activity, Academic Achievement, and Academic Behavior

Academic achievement and physical activity are independent determinants of a child's health (Trudeau & Shephard, 2008). Lack of physical activity contributes to the obesity epidemic in the United States (Dietz, 1998). A Consensus Conference by the Division of Nutrition and Physical Activity at the Centers for Disease Control and Prevention was held in

1993 that resulted in the recommendation that adolescents should engage in three or more sessions per week of activities that last 20 minutes or more and require moderate to vigorous levels of exertion (Jakicic & Otto, 2005). According to the current Consensus Statement issued in 2005 by the same Division of Nutrition and Physical Activity at the Centers for Disease Control and Prevention and as recommended by the Surgeon General, however, school aged youth should participate in 60 minutes of moderate physical activity on most days of the week (Lee, Burgeson, Fulton, & Spain, 2007). It appears that this amount of activity will have a positive effect on the academic performance and musculoskeletal development of children, as well as added beneficial effects on the adiposity in the overweight child (Strong, et al., 2005). Developmentally appropriate, enjoyable physical activity involves a variety of behaviors (Strong, et al., 2005). The role of physical activity in the origin and course of obesity provides a particularly rich area for research and investigation. No studies have yet prospectively defined the precise dimensional amount of physical activity necessary to prevent excessive weight gain in children; in addition, there is a deficiency in research-based information regarding how physical activity and obesity influence academic achievement (Bandini, et al., 2004; Dietz, 2005).

A synopsis of peer-reviewed research confirms several insights related to physical activity and academic performance.

1. Surrendering physical education time for classroom time does not improve academic performance (Ahamed et al., 2007; Dwyer, Blizzard, & Dean, 1996; Sallis, et al., 1999; Shephard, 1996).

2. Higher physical fitness scores are significantly correlated with stronger academic performance (Castelli, Hillman, Buck, & Erwin, 2007; Chomitz et al., 2009; Dwyer, Sallis, Blizzard, Lazarus, & Dean, 2001).
3. Regular participation in physical activity is significantly correlated with improved academic performance as measured by teacher grades (Nelson & Gordon-Larson, 2006; Pate, Heath, Dowda, & Trost, 1996).

According to the American Association of School Administrators (AASA) and sanctioned by the National Council of the Professors of Educational Administration (NCPEA), a secondary analysis of data from the National Center for Education Statistics' Early Childhood Longitudinal Study (12,000+ third graders), a positive relationship exists between physical activity and academic achievement. Students who maintain a higher level of physical activity maintained higher grades and learned at a faster rate than those students who were less physically active (A.A.S.A., 2006). In a series of studies where academic achievement was defined as memory, observation, problem solving, and decision making, positive effects of daily moderate to vigorous physical activity on student performance and scholastic success was demonstrated (Keays & Allison, 1995). A threshold of activity intensity may be needed to bring about changes in the child that contribute to increased academic achievement. Activity of vigorous intensity may be necessary to truly achieve that threshold (Coe, et al., 2006). The interest in academic behaviors has additionally been motivated by an assumption that children who participate in physical activities that encourage cooperation, sharing and compliance to rules, in fact learn skills that also transfer to classroom settings (Taras & Potts-Datema, 2005). Research findings suggest that systematic physical activity programs may actually enhance the development of specific types of mental processing known to be important in meeting challenges encountered in academics (Tomporowski, Davis, Miller, & Naglieri, 2008). Physical activity has a positive influence on concentration and memory (Tomporowski, et al., 2008). If children are healthy, they are in a better position to learn; health and achievement occur concurrently. Physical fitness achievements have recently been significantly associated with better school attendance rates, fewer disciplinary incidents, and better performance on state standardized tests (Welk, et. al., 2010). By addressing the health needs of children, schools can ensure that the children are in attendance, and are physically, emotionally, and mentally in the best position to learn (Cooper, Page, Foster, & Qahwaji, 2003; Deutsch, 2000).

Many school administrators view physical education as reducing instruction time in core academic subjects; there is an historical resistance to physical education (Shephard, 1997). Many of the schools have chosen to eradicate those subjects that are not a part of the high stake testing venues and stringent accountability measures in place through No Child Left Behind (Vail, 2006). Physical education classes have been replaced with other classes in an effort to increase the students' academic achievement as measured by standardized tests (Coe, et al., 2006). The perception is that time spent on nonacademic pursuits negatively impacts children's performance in school (Lindner, 2002). However, in an effort to draw distinction, research involving elementary school children has demonstrated that regular physical activity breaks during the school day may enhance academic performance, academic focus, as well as behavior in the classroom (Barros, Silver, & Stein, 2009). It is important to note, however, that achievement and behavioral responses to physical activity breaks during the school day have not been systematically investigated.

However, there have been few well-designed studies that have addressed this query. *(Appendix D)* The results are mixed among the studies that have attended to this concern.

Discrepancies between research studies may be explained by differences in type, length and intensity of physical activity intervention, study design (randomized versus non-randomized), and method of academic tracking (standardized testing versus individual scholastic grades). Three health surveys involving population-representative samples of children and adolescents from the United States observed statistically significant, positive correlations between physical activity participation and academic performance; yet, none of these studies assessed academic performance with standardized educational tests (Fejgin, 1994; Nelson & Gordon-Larson, 2006; Pate, et al., 1996).

Despite the fact that physical activity has been shown to effectively reduce and prevent childhood weight gain in children 13 years of age and younger, many schools have reduced their commitment to providing physical education and activity in the curriculum (Datar, Sturm, & Magnabosco, 2004; Gortmaker et al., 1999). A survey conducted by the Institute of Medicine recognized that 8% of elementary schools, 6.4% of middle schools, and 5.8% of high schools provided daily physical education for all students for the entire school year (Committee on Prevention of Obesity in Children and Youth, 2005). More recent estimates actually show that only 3.8% of elementary schools provide daily physical education, reinforcing the fact that most children get little to no regular physical activity while in school (Lee, et al., 2007).

Numerous associations between mind and body have been documented. There are reasons to believe physical activity could aid the learning process and that quality physical education could contribute to the academic and intellectual development of students (Jensen, 2000). A review of over one hundred studies, mainly adult studies, deduced that physical activity is associated with select advantages related to academic achievement, specifically mathematics, acuity and reaction time (Thomas, Landers, Salazar, & Etnier, 1994). Physical activity has beneficial influences on behavior and cogntive funtioning that may result in improving student's academic achievements (Coe, et al., 2006; Sallis, et al., 1999; Tomporowski, et al., 2008). Several studies provide encouraging findings about the effects of enhanced physical education on academic performance in school children. These studies did not show that devoting increased time to physical education harmed academic performance (Sallis, et al., 1999). Although there has been no evidence to date to show that maintaining or increasing physical activity during school time negatively impacts academic achievement in other subjects, there remains continued concern that physical education classes could detrimentally consume instructional time (Carlson, et al., 2008). The fear, however, that an increased allocation of time to physical activity during the school day has a negative effect on attainment in other academic subjects is groundless (Shephard, 1997). It has been conjectured that adding time to academics by taking time from physical education programs not only does not enhance grades in these subjects but may actually have an overall adverse effect (Shephard, 1997; Sibley & Etnier, 2003; Trudeau & Shephard, 2008).

A recent analysis of secondary data rendered some interesting findings when combined with a multistage probability design (Carlson, et al., 2008). Researchers analyzed a nationally representative sample of over 5000 students from the 1998-1999 kindergarten class as they progressed through grade five. These students were examined with physical education time and mathematics and reading scores collected from classroom teachers. Results revealed that girls with the highest exposure of physical education (70 minutes or more/week) exhibited significantly higher achievement scores in mathematics and reading; no such association was observed for the boys (Carlson, et al., 2008). Additionally, this evaluation revealed that the overall exposure to physical education in this representative sample was much lower than the national Healthy People 2010 objective of daily physical education, with only 12.6% meeting the objective.

Several pivotal studies in Thailand found that being or becoming overweight in adolescence was associated with poor school performance, although this was not the case for younger children (Mo-suwan, Pongprapai, Junjana, & Puetpaiboon, 1998). This particular research in Thailand showed that in 12-18 year olds, school performance as measured by grade point average (GPA) was associated with the students' current BMI status. Overweight in this group was related to a low mean GPA and significant risks of having low Thai language and math scores. An upward change in BMI status was associated with a greater risk of having a low mean GPA. Such effects of overweight on GPA scores were not seen in the younger children (8-11 years) and could possibly be a lag effect of adiposity on academic performance (Datar, et al., 2004). Since the studies showing that obesity is inversely related to academic achievement are correlational in design, the relationship could turn out to be either causal or consequential.

Although cognitive function and physical activity are considered to be independent determinants of a child's health, they work synergistically on the ability of a child to learn and achieve (Coe, et al., 2006; Trudeau & Shephard, 2008). Many school systems have reduced physical education and/or eliminated physical activity. In fact, less than 6% of the nation's schools currently provide daily physical education for the entire school year (Burgeson, Wechsler, Brener, Young, & Spain, 2003). Despite the current recommendation by the Center for Disease Control and Prevention to participate in 60 minutes of moderate to vigorous physical activity on a daily basis, less than one-third of high school students actually meet these current guidelines (Strong, et al., 2005).

Research suggests that systematic physical activity programs may actually enhance the development of specific types of mental processing known to be important in meeting challenges encountered in academics (Tomporowski, et al., 2008). Academic learning per unit of class time is actually enhanced in physically active children. When a substantial proportion of curricular time (14-26%) is allocated to physical activity, learning seems to proceed more rapidly per unit of classroom time (Shephard, 1997). Children receiving physical education showed an acceleration of psychomotor development, increased cerebral blood flow, greater enthusiasm, enhanced nutrient intake, and increased self-esteem (Shephard, 1997). An impressive link is evident between exercise and improvements in behavioral compliance and academic performance in school settings (Dwyer, et al., 2001; Welk, et al., 2010).

The importance of physical activity for overall physical health is recognized, but the objectively measured dimensions of physical activity on academic performance is not as well researched. In a series of studies where academic achievement was defined as memory, observation, problem solving, and decision making, the positive impact of daily moderate-to-vigorous physical activity on scholastic success was demonstrated (Keays & Allison, 1995).

Physical activity has a positive influence on concentration and memory (Tomporowski, et al., 2008). Physical activity has beneficial influences on behavior and academic achievement that may result in improving student's academic achievements (Coe, et al., 2006; J. F. Sallis, et al., 1999; Tomporowski, et al., 2008). Several studies provide encouraging findings about the effects of enhanced physical education on academic performance in school children. These studies did not show that devoting increased time to physical education harmed academic performance (Sallis, et al., 1999). There has been no evidence to date to show that maintaining or increasing physical activity during school time (such as physical education classes) negatively impacts academic achievement in other subjects. Research consistently shows that school-based physical education or activity does not adversely affect academic performance.

Yet, there remains continued concern that physical education classes could detrimentally consume instructional time (Carlson, et al., 2008). The fear, however, that an increased allocation of time to physical activity during the school day may have a negative effect on academic subjects is groundless (Shephard, 1997). A recent review of the literature from the Division of Adolescent and School Health (DASH) provided confirmation that increased time in physical education appeared to have a positive relationship on academic achievement (Centers of Disease Control and Prevention, 2010). It has been conjectured that adding time to academics by taking time from physical education programs not only does not enhance grades in these subjects but may actually have an overall adverse effect (Shephard, 1997; Trudeau & Shephard, 2008). Objective monitoring of physical activity dimensions will add defense to the argument related to the consequences and/or benefits of physical activity during school hours, either in the form of revised activity programs in physical education classes or increased frequency of activity breaks or recess. The academic implications, as measured objectively by standardized tests and subjectively by teacher grades, as far as this researcher can determine has never been correlated to the objective measure of physical activity dimensions.

A wide range of methodologic approaches to the measurement of physical activity, weight status, sleep characteristics, and academic performance measures exist. Well-designed empirical studies of these relationships are scarce (Sigfusdottir, Kristjansson, & Allegrante, 2007). There are various types of home physical activity monitoring instruments available; yet there are no accepted universal guidelines in children. Sleep monitoring at home is void of normal standards for frequency, lengths, and consequences of nighttime arrousals or wake episodes. Academic performance is measured either by subjective teacher evaluations or various standardized tests that compare poorly across state lines. Consequently it is very dubious to contrast study results with such diverse procedures and approaches. However, while the body of published work is small and methodologically limited, the preponderance of evidence from these studies does show that overweight/obese children do not perform as well or attend school as much as their healthy counterparts (Taras & Potts-Datema, 2005). In addition, recent research reveals that elevations in BMI in grade-school children is associated with decreasing efforts in their respective academic setting (Ramaswamy, Mirochna, & Perlmuter, 2010). Children who are healthy are in a better position to learn and to regularly attend school. Health and achievement occur concurrently. By addressing the health needs of children, schools can ensure that the children are in attendance, and are physically, emotionally, and mentally in the best position to learn (Cooper, et al., 2003; Welk, et al., 2010).

The implicit belief that physical activity is linked to intellectual abilities goes back as far as ancient Greece (Tomporowski, et al., 2008). Interest was revitalized in the 1930's when a positive association was first scientifically realized between sports participation and intellectual achievements (Davis & Cooper, 1934). The importance of physical activity for overall physical health is fairly well accepted. The positive consequences of physical activity on concentration, mental cognition, and academic performance are not as quickly recognized or acknowledged (Mahar et al., 2006). Many confounders make it difficult to isolate the effects of the dimensions of physical activity and the often subjective scoring of academic achievement.

Growing evidence suggests that many forms of physical activity make important contributions to increasing brain reserve (Mortimer, Snowdon, & Markesbery, 2000). Research results from the early 2000's suggest a positive impact of regular physical activity on learning and memory at all ages (Trudeau & Shephard, 2010). In addition, the optimal amount of physical activity per day (at least 60 minutes) can be provided without jeopardizing academic performance (Trudeau & Shephard, 2010). Active students compensate for a reduction of academic instruction time by greater efficiencies related to the learning process (Shephard, 1997). Participation in physical education, school sports programs, and free-time during recess are likely to increase attachment to school and self-esteem, indirect but important factors in academic achievement. The interest in academic behaviors has additionally been motivated by an assumption that children who participate in physical activities that encourage cooperation, sharing and compliance to rules, in fact learn skills that also transfer to classroom settings (Taras & Potts-Datema, 2005).

In addition, recent structural analysis and brain mapping utilizing relatively novel methods of neuroimaging reveal that higher body tissue fat content is strongly associated with brain volume deficits and atrophy (Gazdzinski, Kornak, Weiner, Meyerhoff, & Rer Nat, 2008; Pannacciulli et al., 2006; Raji et al., 2009; Taki et al., 2008). More specifically, higher body tissue adiposity may have harmful effects on brain structure and cognitive abilities. These results suggest that factors that promote obesity may predispose to cognitive impairments. One of the most commonly proposed mediators for the relationship between an increased body tissue adiposity and brain structure include reduced exercise (Colcombe et al., 2003). Given the premise that a lack of physical activity is an important contributing factor in the development and preservation of childhood obesity, the complex triangular association amongst activity, weight, and cognition deserve further investigation (Hill, et al., 2003; Pratt, et al., 1999; Rowlands, et al., 1999).

The brains of physically active children show evidence of more extensive processing during tasks, as well as faster reaction times (Jensen, 2000). Students who sustain a higher level of physical activity maintain higher grades and learn at faster rates than those students who are less physically active (Byrd, 2007). Obese children are four times more likely to report impaired school function than normal weight children (Schwimmer, et al., 2003). Yet, physical activity classes have decreased markedly in this country with the introduction of the No Child Left Behind Act (NCLB) of 2001. The mandates of NCLB compel educators to improve academic skills. Many of the schools attempt to accomplish this daunting task by eliminating any non-academic subject, possibly at the expense of the physical health of the children (Vail, 2006). A false dichotomy has emerged in many school districts that view time devoted to physical education as a diversion in monies and a distraction in time from academic pursuits. Consequently, physical education is often perceived as a reduction in instruction time in core academic subjects (Shephard, 1997). The perception is that time spent on nonacademic pursuits negatively impacts children's performance in school (Lindner, 2002).

Children need free play at school and at home. Activity breaks can improve academic performance as well as academic focus and behavior (Barros, et al., 2009; Jarrett et al., 1998; Mahar, et al., 2006). The time designated for free play at school is called recess. Recess is an interlude as well as a change of pace. Studies show that there are many beneficial effects of recess on a child's performance and behavior in school (Jarrett, et al., 1998; Pellegrini, 1995). Young children not only play in bouts of activity but they also appear to learn better in bouts. Study results reveal that a break during the school day of $\geq$ 15 minutes was associated with better teacher classroom behavior ratings (Barros, et al., 2009). However, since the late 1970s, between school budgetary restraints and the directives of NCLB, children have lost approximately 12 hours of free time per week, to include a 25% decrease in play and a 50% decrease in unstructured outdoor activities (Juster, Ono, & Stafford, 2004).

Physical Activity and Weight Status

Physical activity includes any body movement achieved by contraction of skeletal muscles with the consequent increase in energy expenditure above resting levels (Caspersen, et al., 1985). Not only does the lack of physical activity appear to be an important contributing factor in the development and preservation of childhood obesity, it appears to hold a more consistent relationship to weight than excess energy intake does (Weinsier, Hunter, Heini, Goran, & Sell, 1998). Although the proportion of overweight adolescents has increased, the risk factors are not well understood. Programs of moderately intense exercise of thirty to sixty minutes in duration (3-7 days/week) lead to a reduction in total body and visceral adiposity in overweight children. (*Appendix E*) Levels of physical activity intensity, however, have historically not been collected or well documented in pediatric populations. With the use of accelerometers and objective monitoring, the association between physical activity and weight status suggested that higher physical activity intensity in children may be more important than total activity (Ness et al., 2007).

Two longitudinal studies (secondary analysis) showed significant decreases in moderate to vigorous physical activity through the use of accelerometers as children advanced in age. A 17-31% decline in moderate to vigorous activity was seen in children as they were followed from 9 years of age to 15 years of age (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). This particular study examined secondary data from a cohort that had been followed since birth as part of a multisite study with 10 geographic locations. Over one thousand children were followed for 6 years, with four points of contact. The children wore uniaxial accelerometers with sixty second epochs for a minimum of seven hours/day for at least four days on four separate occassions throughout the study. Several strengths of this study are noted. The size of the sample, the repeated measure examinations, the longitudinal design, the inclusion of weekdays and weekends, and the objective nature of the activity monitoring all added to the power of this research. The study was also limited in several ways. The sample was not nationally representative (lacking racial and ethnic diversity) and thus the findings are not fully generalizable. The use of accelerometers, especially uniaxial monitors, tend to underestimate the activity of youth who engage in contact sports or water activities. The length of epoch (one minute) may encourage missed activity bouts in children. Lastly, this particular study was conducted at a time when the rapid escalation of obesity in the United States was prominent. Consequently, it is difficult to determine if the longitudinal change in activity is a consequence of the age of the participants or the manifestation of a secular trend. Regardless if the cause of the decreased physical activity is a secular phenomenon or a developmental occurance, the declining moderate-vigorous activity trajectory as children age is concerning. An additional study is seen that also measured physical activity with accelerometers, but in a larger and more representative U.S. population (Troiano et al., 2008). The NHANES data was gathered from 600 children between the ages of 6-11 years of age. A uniaxial accelerometer was used to collect daytime activity counts on the children, who wore the monitor anywhere from one to four days. The epoch length was set at one minute and the cut points for intensities were arbitrarily set at a rate slightly higher than for adults to account for the increased metabolic rate of children. The results from this data showed that although 42% of children aged 6 to 11 years obtained the recommended 60 minutes/day of physical activity, a mere 8% of adolescents achieved this goal. The large, diverse sample size lends itself to many interesting findings as related to sex, age, and race of physical activity intensities. The use of the accelerometers in this study added to the confirmation of the unreliability of self-reporting as well as the deficiency of moderate-vigorous activities enjoyed by children as they developed.

In an attempt to explain the role of physical activity in preventing obesity during adolescence, a ten year longitudinal study with a large cohort was conducted. Eleven hundred white and black U.S. girls were assessed at four intervals and followed from ages 9/10 years of age to 18/19 years of age (Kimm et al., 2005). This multicenter study was funded by the National Heart, Lung and Blood Institute. Participants self-reported amount and intensity of overall physical activity status according to category classifications. Adiposity was measured by skinfold thickness. Body mass index was calculated annually from height and weight measurements. Activity data as well as food intake data were gathered through questionnaires. Results showed a significant relationship between physical activity and changes in weight during the crucial transition years from childhood to adulthood (Kimm, et al., 2005). A decline in activity was associated with an increase in BMI: a relationship was not seen, however, with energy intake (Kimm, et al., 2005). These adolescent girls reported a marked decline in physical activity as they matured. Their rate of overweight and obesity doubled while their concomitant reported energy intake did not increase accordingly. Physical activity was shown to play a correlational role in the rate of weight gain in adolescent girls. This multicenter study was strengthened by the longitudinal design, the large cohort, and the interracial sample mix. The self-reported measures of physical activity and dietary intake, especially in adolescent females, served to weaken the structure of the study and the integrity and reliability of the results. In addition, skin fold assessments have been shown to be dependent on the scorer and over the course of the ten year study, many assessors would have been utilized. A different assessment investigated only male adolescents. In this Canadian study, slightly less than four hundred adolescent males between the ages of 11 years and 17 years of age participated with three days physical activity diary-keeping. Body composition and fat distribution data were gathered through skinfold thickness and body weight calculations. Reported results revealed that only twelve percent of the population practiced vigorous physical activity on a daily basis, while thirty percent self-reported no participation in any daily physical activity (Dionne, Almeras, Bouchard, & Tremblay, 2000). Findings showed that excess abdominal fat accumulation could be prevented by regular participation in vigorous physical activities such that higher intensity activities were linked with a lower body fat accumulation (Dionne, et al., 2000). The population was very homogenous, though, and lacked diversity or generalizability of results.

In a 2 year longitudinal study, the impact of physical activity on 97 preschool children was assessed through the use of uniaxial accelerometers twice yearly for five days. This cohort was an off-shoot of The Framingham Children's Study, a longitudinal study of childhood cardiovascular risk behaviors. The body fatness was evaluated and quantified using skinfold measures. According to this analysis, the children who engaged in low levels of physical activity gained substantially more subcutaneous fat that did more active chidlren. Consequently, the cardiovascular relative risk estimate was slightly higher for children with more body fat (Moore, Nguyen, Rothman, Cupples, & Ellison, 1995). This study was then extended for an additional five years in an effort to test the hypothesis that accumulated physical activity over a seven year period (from 4 to 11 years) was associated with fatness at eleven years (Moore, et al., 1995). The study corroborated the evidence that higher levels of physical activity during childhood led to the acquirement of less body fat by preadolescence. The findings suggested that the protective benefits of physical activity at an early age were not sustained unless the activity level was maintained (Moore, et al., 1995). In addition, adiposity rebound occurred at a later age in the most active children, thus further reducing their risk of obesity later in life (Moore, et al., 1995).

Using a three year longitudinal design and objective physical activity measures, the relationship between physical activity and body fatness were measured using accelerometers and dual energy x-ray absorptiometry (DXA) (Janz, Burns, & Levy, 2005). Baseline data on this cohort (*n* = 379) was initially gathered during their first weeks of kindergarten (5 years of age) and followed through the third grade (8 years of age). Sedentary levels and physical activity levels were tracked in this research semiannually for three years. Intensities of physical activity were objectively recorded on a uniaxial accelerometer in one minute epochs for eight daytime hours. Sedentary behaviors were tracked as television watching as reported by the parents, usually in bundles of thirty minute increments. Children that maintained higher levels of intense activity associated with low levels of television viewing showed less adiposity as measured by DXA (Janz, et al., 2005). This particular research utilized the uniaxial accelerometer to track the four days of seasonally specific activity as supplemented by parental proxy reports of sedentary behaviors. Two energy specific equations were mixed to set and interpret energy cut point limits. Adiposity was measured at each clinical visit using the gold standard body composition measure, DXA. Comparisons of specific times of gender specific daytime activities were analyzed and tracked. This unique combination of tracking longitudinal changes in activity and adiposity confirmed previous patterns of activity seen as children mature. The design and implementation of the study was rigorous. The addition of a triaxial accelerometer could eliminate the ineffective parental reports. A more recent secondary analysis by these same researchers hypothesized that physical activity during early childhood would result in less fat mass accumulation later in childhood (Janz et al., 2009). Using a cohort of three hundred and thirty-three children from the Iowa Bone Development Study, data was gathered at three points of time for three age groups, 5 years, 8 years, and 11 years of age. The data analysis with mixed regression models statistically showed that early physical activity affects later fat mass in children, even after adjustment for concurrent physical activity. There appears to be a pathway between early physical activity and later fat mass independent of the effect of accumulated physical activity. Significant associations continue to persist providing evidence that early physical activity (at five years of age) affected later fat mass (11 years of age), especially in boys (Janz, et al., 2009). Physical activity at an early age may influence a type of fatness genotype later in life, suggesting that children who are less physically active early in life may be more susceptible to fat accumulation later in life (Janz, et al., 2009). This research is strengthened by the longitudinal design and the use of objective monitoring tools. However, these research results are limited by the Midwestern convenience sample size used and the relatively high socio-economic background of the participants. Additionally, confounders were not considered, such as energy intake, sedentary time, and demographic factors. The study would have benefited from the use of a smaller epoch size and a triaxial accelerometer. Althought cut points have not been standardized in this population, the energy equation used by these researchers has been the accepted predictor of cut points in children.

Sleep, Physical Activity, and/or Weight Status

Approximately 15 million children get inadequate sleep in the United States (NASPE, 2004; National Sleep Foundation, 2006). There is increasing epidemiological evidence suggesting a link between sleep duration and obesity in children, revealing that hours of sleep per night of children are inversely related to their body mass (Agras, et al., 2004; Gangwisch, et al., 2005; Sekine, et al., 2002; von Kries, et al., 2002). Many pediatric research studies have acknowledged a positive association between lack of sleep and excess weight gain (Chaput, Brunet, & Tremblay, 2006; Chen, Wang, & Jeng, 2006; Knutson, 2005; Padez, Mourao, Moreira, & Rosado, 2005; Reilly, et al., 2005). Although short sleep appears to be a marker of unfavorable health outcomes, the above noted pediatric sleep studies relied predominantly on questionnaires to verify sleep qualities and quantities. Objective sleep data has been shown to consistently yield more accurate details than subjective sleep diaries. Parental proxy reporting of children's sleep time and sleep habits also tend to be overestimated and thus inaccurately described, particularly in older children who fall asleep independently in their own rooms (Nixon, et al., 2008). Although parents frequently report on symptoms such as daytime fatigue or low energy as a result of poor nighttime sleep, precise sleep time and number / duration of nighttime awakenings is only approximately reported in children who are old enough to get into bed by themselves. Although sleep logs and actigraphy both yield similar accounts of sleep timing, sleep duration, and sleep onset and offset, the two methods of recording reveal drastically different results in relation to the reporting of sleep latency and the number and duration of night wakenings (Ancoli-Israel et al., 2003). Agreement rates and accuracy between parents' sleep logs of a child's sleep/wake cycle and actigraphy appear to decline with age of the child and length of the study period (Sadeh, 1996).

Based on energy cost, sleep is considered the most sedentary of human activities. It has been shown that short average duration of sleep is associated with excess body mass (Gangwisch, et al., 2005; Patel & Hu, 2008; Taheri, et al., 2004; Tremblay, Esliger, A., & Colley, 2007). The relationships between sleep, activity, and health outcomes are likely moderated by many factors. Yet, short sleep duration has been shown to be a better predictor of overweight and obesity than parental obesity, low level parental education, low family income, extended television viewing, or limited physical activity (Chaput, et al., 2006).

The implications of the association between the health indicators of physical activity and sleep characteristics have been observed in a few recent studies. Research has shown that sleep disturbances are inversely associated with daytime physical activity in adolescents (Gupta, et al., 2002). Physical activity has been significantly correlated to health promoting behaviors such as improved sleep quality through adequate sleep in adolescents (Chen, et al., 2006). Overweight adolescents appear to have lower activity levels, consequently reduced energy expenditure, and subsequently less total sleep time (Agras, et al., 2004). The associations between sleep, physical activity and other specific health outcomes, however, lack not only objective epidemiological validation but also underscore a marked void in data from elementary school-aged children. Since sleep requirements vary throughout childhood, the definition of short sleep duration is dependent on the age of the cohort. A recent analysis of 2,281 children also illustrated that the shift toward later weekday bedtimes might begin as early as eight or nine years of age (Snell, Adam, & Duncan, 2007). Some pediatric data indicates that the relationship between sleep duration and weight may weaken with age (Patel & Hu, 2008).

Longer sleep duration has also been associated with a greater amount of exercise, although the direction of the association is unclear (Youngstedt, 2005). It is possible that greater sleep duration leads to a higher likelihood for increased physical activity and lower risk of overweight or more physical activity may both increase sleep and reduce weight gain. *(Appendix F*) According to recent research, the only study noted that examined whether sleep modifies the effect of exercise on weight, ghrelin, or leptin, was conducted using a cross-sectional design with a sample of overweight post-menopausal sedentary women (Littman, et al., 2007). There was only limited evidence that changes in sleep characteristics or physical activity induced alterations in the weight of the women. Moreover, the observed differences were not in the direction that the researchers had hypothesized. The weight loss differences between those who exercised were greater for those who slept less (Littman, et al., 2007). Important to note in this study, all sleep data was self-reported by the women. There was only borderline evidence that BMI was associated with sleep measures. As well, there was no evidence that ghrelin or leptin levels were associated with sleep (Littman, et al., 2007). Future longitudinal studies including population-based samples using objective measures of sleep and long follow-up may help to clarify these relationships. This intriguing but obvious incomplete realm of research lacks specific physical activity and sleep characteristic objective measures, especially in children. The question posed begs the query whether exercise can ameliorate weight through sleep modification.

Childhood sleep patterns have recently come to be identified as potential risk factors for obesity/overweight issues. Overweight children tend to sleep on average about 30 minutes less than nonoverweight children (Agras, et al., 2004; Sekine, et al., 2002). Accordingly, greater than 11.5 hours of sleep on a daily basis for 5 and 6 year olds reduced the risk of obesity and excessive body fat to less than half (von Kries, et al., 2002). The impact of sleep duration appears to be dose-dependent. A recent longitudinal study also substantiated that short sleep duration, as measured by actigraphy, was shown to be an independent risk factor for obesity/overweight (Nixon, et al., 2008). The impact of sleep on various health indicators warrants objective measures to facilitate accurate recommendations and guidelines.

There is an age related association between sleep and obesity. Young children (between 5-10 years of age) have a stronger, inverse relationship between short sleep duration and obesity than other age groups. A recent study showed that children in this age group who slept less than nine hours/night had a higher prevalence of obesity than those who slept more than 10 hours/night (Shi et al., 2010). The frequency of obesity almost doubled, 22.3% versus 11.5% respectively, in this age group. The age related association between sleep and obesity has intrigued researchers lately. Children under the age of five who received less than ten hours of night time sleep were twice as likely five years later to become overweight or obese (Bell & Zimmerman, 2010). The risk of becoming overweight by the age of seven was considerably greater for children (3 to 7 years) who slept an average of less than eleven hours per day (Carter, Taylor, Williams, & Taylor, 2011). Furthermore, for each additional hour of sleep, a child's BMI was calculated to be 0.49 lower with a 61% lower risk of being overweight/obese by age seven (Carter, Taylor, Williams, & Taylor, 2011). This particular unique longitudinal study measured sleep duration objectively with an accelerometer and fat mass with bioelectrical impedance and dual energy x-ray absorptiometry. The data substantiated that young children with inadequate sleep were at an increased risk of overweight as a result of increased fat mass deposition (Carter, Taylor, Williams, & Taylor, 2011).

An inverse association reported in several longitudinal studies has shown that when young children (up to age 12 years) sleep fewer hours/night, they are at an increased risk of becoming overweight at a later age, during childhood as well as adulthood (Chaput, Brunet, & Tremblay, 2006; Chen, Beydoun, & Y., 2008). Interestingly, progressive Tanner stages, BMI increases, and decreased sleep duration have recently been shown to be interrelated, adding to concerns related to reductions in sleep during puberty (Rutters, Gerver, Nieuwenhuizen, Verhoef, & Westerterp-Plantenga, 2010). Sleep difficulties are positively associated with overweight and obese preadolescents, yet the direction and causality of this association is not yet clear (Liu, Divya, Faught, Wade, & Cairney, 2011).

The complex relationship between physical activity and weight status depends in large part on the method of measurement. The mode of activity measurement strongly influences the strength of the activity-health relationship, such that studies using objective assessment tools show stronger results (Rowlands, et al., 2000). The inconsistency in studies investigating the relationship between physical activity and obesity emphasizes the need for accuracy and uniformity in measurements and definitions. The association between physical activity and body mass index appears to be more reliably reported when the activities, as well as the weight status, are objectively measured. However, despite the assumption that an inverse relationship between activity levels and body fat in children should be an easy supposition to prove, the evidence is ambiguous (Rowlands, et al., 2000). Much of the disparity is related to the lack of consistency when measuring activity levels in children.

Many discrepancies and questions exist regarding the actual role of weight status as it relates to activity, especially when physical activity is measured as either energy expenditure or time in a given behavior. It has been suggested that the link between physical activity and weight status should be conceptualized as a behavior, not as energy expended (Rowlands, et al., 2000). Weight management should focus not only on increasing physical activity but also on decreasing sedentary behaviors. Such an approach has enormous potential for promoting healthy weight status through performance manipulation. Viewing the association between physical activity as a behavioral risk factor and the condition of obesity as a correlate of this conduct enables the employment of behavior modification. The intention is to balance the rate of weight gain while maintaining developmental gains appropriate for children. Encouragement of energy balance behaviors is a way to promote positive health outcomes.

It is generally agreed that the fundamental balance of energy expenditure and energy intake are at the heart of the obesity epidemic. Factors that contribute to this balance often elude us. The complexity of subtle consequences or confounders remain incompletely understood. Specifically, sleep may very well be a factor that alters both sides of the energy balance equation (Taheri, 2006). Several cross-sectional studies have recognized a dose-response relationship between short sleep duration and excess body weight in children (Chen, et al., 2006). Absent from the research literature are studies that have considered weight status in the circadian configuration of objectively monitored activity. Additionally, most studies investigating the effect of sleep on energy have concentrated on adults. However, children have shown a robust relationship between sleep duration and excess body weight and may be most vulnerable to the consequences of sleep loss (Reilly, et al., 2005).

Sleep, Academic Achievement, and Academic Behavior

According to parental reports, nearly sixteen percent of school-aged children have difficulty falling asleep (Liu, Liu, Owens, & Kaplan, 2005). Furthermore, in a recent meta-analysis of over 50 studies, sleep deprivation led to significant impairment of human performance (Sadeh, Gruber, & Raviv, 2003).

Sleep is an active, rhythmic, recurring, and reversible behavior that serves many functions (Curcio, et al., 2006). Sleep deprivation can impair learning and memory for both knowledge development and skills performance (Gais & Born, 2004). Insufficient data exists, however, regarding the specific effects of inadequate sleep in children (Dahl, 1996). Minimal efforts have been invested to explore these issues of fragmented sleep in school children: this neglect is intriguing considering the importance of this period in brain maturation and cognitive development (Welsh, et al., 1991). It is well established, though, that the integrity of learning and memory processes are fundamental in school achievement and academic performance, particularly in children (Curcio, et al., 2006). Academic performance is clearly linked to sleep habits and daytime sleepiness levels (Wolfson & Carskadon, 1998). Poor sleep quality can seriously impair students' academic achievement and behavioral performance. (*Appendix G*) Sleep quality, more than sleep quantity, has important implications to school performance (Epstein, Chillag, & Lavie, 1998; Pilcher, Ginter, & Sadowsky, 1997).

The role of sleep in neurobehavioral functions such as cognition has been widely studied in adults. It has been demonstrated that sleep can influence learning and memory function and conversely learning and training can influence sleep (Maquet, 2001). Despite the fact that childhood is a time for brain maturation and cognitive development, minimal research has been conducted on the effects of various sleep patterns (disruptions, fragmentations) in children. Available literature suggests that there is a link between sleep and cognitive performance in children (Taheri, 2006). Much of the existing research is reliant on subjective appraisals or experimental sleep lab settings (Taheri, 2006). The small amount of objective knowledge on short sleep duration and poor sleep quality has consistently shown a weak inverse relationship to cognitive performance in children (Paavonen et al., 2010). Not only have the long-term effects of short sleep in children never been studied, the varied manifestations of sleepiness in children lack categorical identifications (Touchette, et al., 2007). Although a recent correlational study, through the use of actigraphy, indicated no significant correlation between sleep duration and academic achievement, significance was seen between increased number of night wakenings (fragmentation) and cognition as tested by neurobehavioral tasks (Sadeh, Gruber, Raviv, 2003). Seventy-seven fourth and sixth graders participated in this second study by this group of researchers. The children all wore home wrist actigraphy for six school days between November and May. Sleep was randomly manipulated through individual phone calls to the homes. Sleep was either extended or restricted. The children completed nightly sleep diaries. Neurobehavioral function tests were given to the children twice, once at baseline and once post-intervention. The modest manipulation of sleep in the natural environment of the children was a novel and robust approach for this population. Sleep was either extended by 35 minutes increments or reduced by 40 minute increments for three of the six days. The manipulation of sleep time resulted in significant sleep quality measures. Sleep extension led to a significant increase in number of nighttime wakings while the opposite is true of the sleep restriction. Additionally, the moderate changes in sleep deprivation showed detectable significant effects on the neuropsychological functioning of the children. Also of interest is the finding that these correlations were strongest in children seven to eight years of age (Sadeh, et al., 2002). This study is limited by the lack of baseline sleep data, such that is unclear whether these children where obtaining sufficient sleep. However, the answer to the question of how much sleep is needed for children at different ages is not clear.

One hour of sleep deprivation has also been shown to substantially impair the following day's cognitive and behavioral functioning of ten year olds (Sadeh, et al., 2003). In a recent longitudinal study that employed multiple self-administered sleep questionnaires completed by the mothers, a chronic reduction of one hour of sleep per night resulted in a reduction of cognitive performance in young children (Touchette, et al., 2007). This Canadian research spanned six years for 1500 infants to children six years old. Sleep duration was reported annually by the children's mothers from age 2.5 to 6 years. Behavioral measures were also reported by surveys completed by the mothers. Two types of age appropriate cognitive tasks were given to the children. This homogenous group showed nighttime sleep duration stability in over ninety percent of the children, who were reported to have slept at least ten hours per night through age six. A modest but chronic reduction of sleep in young children was shown to impede their cognitive performance and detrimentally affect their behavioral outcomes. These findings also highlighted a critical period for cognitive and behavioral development that may be jeopardized by short sleep. Additionally, it appears that this critical period in early childhood where the lack of sleep is particularly destructive to various aspects of development even if sleep normalizes later. This study benefits from the very large sample size but is limited by reliance on the subjective measures of sleep quantity and the lack of generalizability with a highly homogenous sample.

Significant correlation was seen between standardized age-related testing and specific sleep variables in a cohort of kindergarteners in one of the first large scale community studies using home actigraphy (Ravid, Afek, Suraiya, Shahar, & Pillar, 2009). One hundred and forty-eight Israeli kindergarten children were studied to determine the difference in sleep patterns between children who did not qualify to progress to first grade compared to the controls that were found to be qualified for first grade. The children wore an accelerometer for one week at nighttime. Parental subjective evaluations were used to supplement this information. Longer sleep latency, reduced sleep efficiencies, increased nocturnal wakenings, and subsequent daytime sleepiness were strongly related to cognitive testing inabilities and a non-readiness for school (Ravid, et al., 2009). Difficulties in falling asleep and long sleep latency are usually associated with both personal and environmental factors. No data was collected in this study related to income of the families and their socioeconomic background. Similarities and disparities in the study group and the control group are vague. The subjective questionnaires may be considered "soft" data.

However, the use of actigraphy over the period of one full week in children who are pre-classified by government standardized testing adds strength to this research.

An association between academic performance and sleep habits have also been suggested by sleep-breathing disorders, often related to obesity complications (Curcio, et al., 2006). Sleep-disordered breathing is a spectrum of disorders ranging from primary snoring to severe obstructive sleep apnea syndromes (OSA). An estimated 10-25% of three to twelve year olds suffer from primary snoring and 10% of these children have OSA (Mitchell & Kelly, 2005). Clinically significant effects on learning and memory function in obese children are a severe consequence of apneic/hypo-apneic events in OSA (Rhodes, et al., 1995).

Recently, sleep deprivation has been shown to produce decreased leptin, increase ghrelin levels, and decreased glucose tolerance (Taheri, Austin, Young, & Mignot, 2004). In adults, sleep deprivation synergistically incites the production of more ghrelin, which stimulates appetite, and reduces the production of leptin, which can suppress appetite through satiation signals (Taheri, et al., 2004). Consequently the suggestion is that sleep deprivation and sleep reduction may be related to hormonal changes that lead to weight gain (Spiegel, et al., 2004). As a result of these physiologic changes, sleep restriction in humans appears to increase hunger and appetite, and lead to an increased risk of obesity (Spiegel, et al., 2004). Additionally, sleep-associated breathing disorders are well-established pulmonary consequences of childhood obesity (Lobstein, Baur, & Uauy, 2004).

Hours of sleep per night is inversely related to overweight status as measured by BMI in cross-sectional studies as well as in longitudinal studies (von Kries, Toschke, Wurmser, Sauerwald, & Koletzko, 2002). The link between sleep duration and obesity has been well established in adults (Gangwisch, Malaspina, Boden-Albala, & Heymsfield, 2005; Vorona, et al., 2005), but comparatively little is known about this relationship in younger children. Poor sleep quality has been associated with a lowered sense of well-being and decreased quality of life in young adults (Pilcher, et al., 1997). The actual role of sleep traits in obesity is not well understood. Several studies, though, have provided evidence for an association between shorter sleep duration and an increased likelihood of overweight in children, ages 3 to 7 years and/or 10 to 17 years of age (Gupta, Mueller, Chan, & Meininger, 2002; Kagamimori, et al., 1999; Sekine, et al., 2002; Sugimori, et al., 2004; Reilly, et al., 2005; Beebe, et al., 2007). The interpretation of these studies is limited, however, by racial and socioeconomic homogeneity as well as a noticeable dearth of longitudinal data.

Additionally, sleep disruptive behaviors have also been shown to impact academic performance. One in ten primary school children (grades 4-6) have been found to have snoring episodes (frequently or always) (Ali, Pitson, & Stradling, 1993). Children who snore habitually had at least twice the risk of performing poorly at school, with this association becoming stronger with increasing snoring frequency (Urschitz et al., 2003). Specifically, under achievements in mathematics, science, and spelling were compounded by impaired attention capacity, lower memory and intelligence scores (Blunden, Lushington, Kennedy, Martin, & Dawson, 2000).

One particularly interesting prospective study in a cohort of 150 children from the United States indicated a relationship between shorter sleep duration between the ages of 2 and 5 years with an increased overweight risk at 9.5 years of age (Agras, et al., 2004). According to this research study, the risk factor for obesity was seen as a difference in sleep patterns, with overweight children sleeping about 30 minutes less than nonoverweight children. This dissimilarity in sleep length was almost entirely accounted for by less daytime naps. Correlates of this sleep pattern suggested that these overweight, short-sleepers had lower activity levels, thus affecting their weight status through reduced caloric expenditure. This led to the conclusion that children with low activity slept less during the day secondary to less tiredness (Agras, et al., 2004). Sleep trends were also reported in a cross-sectional study of over eight thousand 6-7 year old children from the Toyama Birth Cohort Study (Sekine, et al., 2002). Information on physical activity, sleeping habits, and energy intake was tallied from questionnaires filled in by parents. Anthropometric measures were obtained at the schools. Correlational results confirmed the association between physical inactivity and childhood obesity. In addition the dose-response relationship between short sleeping hours and obesity was substantiated, even after adjusting for physical activity. Eating habits and exercise habits as reported by the parents were not significantly associated with obesity according to this study (Sekine, et al., 2002). The incredibly large sample size in this study adds power to the associations, but the subjective reporting of sleep habits by the parents was a limiting factor. The physical activity variable was reported and ranked by comparing the activity of the child with his/her peers. This resulted in a skewed distribution and the accuracy of physical activity reporting was questionable. Additionally, sleep disturbances and socioeconomic status indicators were not collected in the questionnaires, leaving the data unadjusted for these potential confounders. Additional clarification is needed to ascertain whether obesity leads to a shortage of sleep or if short sleepers are at risk of obesity (Sugimori, et al., 2004).

Another prospective research study looked at the association of short sleep duration or sleep problems and childhood overweight in 785 third and sixth graders (Lumeng, et al., 2007). Through secondary analysis of data, this study considered gender, race, and maternal education in the association of sleep duration and weight status in these children. Information on sleep duration and problems was obtained by parental reporting. Anthropometric measures were performed by trained research assistants at all ten sites. Shorter sleep duration in 6^{th} grade was independently associated with increased concurrent risk for overweight. Interestingly, the longitudinal relationship with shorter sleep duration in 3^{rd} grade was associated with increased likelihood of future overweight in the 6^{th} grade, independent of the weight status in 3^{rd} grade. Furthermore, for every additional hour of sleep in 6^{th} grade, the child was about 20% less likely to be overweight in 6^{th} grade and for every additional hour of sleep in 3^{rd} grade, the child was about 40% less likely to be overweight in 6^{th} grade (Lumeng, et al., 2007). Objective measures of sleep problems were not performed. In addition, no questions related to snoring or breathing difficulties were queried. Instead, this study used an adapted version of the Children's Sleep Habits Questionnaire (CSHQ) making it difficult to compare results with other studies that used the original version. The size of the study sample does add strength to this study. The unique perspective of the longitudinal prospective design adds new information to the science of obesity and sleep in children.

Weight Status, Academic Achievement, and Academic Behavior

Research shows that overweight and obese children are far more likely than normal weight peers to repeat a grade in school or to miss more than two weeks of school per year (Dentzer, 2010). The empirical correlation between weight status and academic achievement and behavior is less obvious due to the complexity of the associations and connections. Direct indicators of academic achievement include grade-point averages, scores on standardized tests, course grades, attendance, tardiness, homework performance, study skills, and IQ scores while indirect estimates include measures of concentration, memory, and classroom behavior (Carlson et al., 2008; Strong, et al., 2005). In addition to classroom behavior, self-esteem, self-image, school satisfaction, and school connectedness have also been postulated as indirect determinants of academic achievement (Trudeau & Shephard, 2008). The use of such a plethora of different measures is a limitation to the comparability between different studies. Rating systems vary across different schools and consequently even grade point averages appear to be non-objective indices (Curcio, Ferrara, & De Gennaro, 2006). Data collection in studies performed to date are based more on surveillance by parents, teacher, or students; a method that warrants some level of validation (Taras & Potts-Datema, 2005). Consensus and preference for the use of standardized tests in the assessment of academic achievement, rather than teacher-assigned grades, has been recommended to avoid any bias (Sallis et al., 1999).

School studies have found a higher percentage of overweight children among low-achievers; this association between overweight and under-achievement appears to persist into adulthood (Guillaume & Lissau, 2002). The World Health Organization (WHO) designed a project to assess the extent of the relationship between basic anthropometric measurements and educational level as measured in years of schooling in 26 different populations (Molarius, Seidell, Sans, Tuomilehto, & Kuulasmaa, 2001). Differences in relative body weight by education were evaluated over a ten year period (Molarius, et al., 2001). A statistically significant inverse relationship between educational level and BMI for women in the majority of populations was noted; while lower education was associated with higher BMI in only about 50% of the male populations (Molarius, et al., 2001). In addition, an independent study conducted by the National Public Health Institute of Finland, provided statistics verifying that not only were the mean BMIs in both men and women lowest among those with the highest education, the differences between education and body mass index was reaffirmed to be more dramatic in women (Lahti-Koski, 2002). In the process of studying the relationship between educational attainment and overweight status, a nationally (U.S.) representative sample of over 10,000 subjects (ages 16-24 years) were followed for seven years; after which a cohort of 370 overweight women verified that higher BMI was statistically significant with fewer years of schooling (Gortmaker, Must, Perrin, Sobol, & Dietz, 1993). In addition, a recent study found consistent evidence of a negative relationship between body weight and wages for white women (Cawley, 2004). Based on this work, an economic study was conducted at the University of Georgia to examine whether early (young) human capital accumulation is adversely affected by obesity. This research was found to not only confirm relationships between weight status and earning capacity, it also added substantiation to the significance of overweight tracking from adolescence into adulthood (Sabia, 2007). If increased weight reduces the academic performance of adolescents, then the obesity-specific wage gap may reflect only part of the economic burden of obesity. Based on these premises, a secondary analysis of data from the National Longitudinal Study of Adolescent Health (Add Health) was performed (Sabia, 2007). Anthropometric measurements on adolescents (14-17 years of age), were provided by the initial CDC data collection, while grades were self-reported by the adolescents as part of the survey tool. The findings provided evidence of a significant negative relationship between body mass index and grade point average for white females, a difference of 50-60 pounds of weight was associated with an 8 to 10% difference in standing in the GPA distribution (Sabia, 2007).

Regrettably, however, the cause and effect for the association between weight status and poor academic performance has not yet been established through research (Taras & Potts-Datema, 2005). Many studies have suggested that obesity is a marker, not a cause, of low academic performance. The causative role of obesity in school performance is unclear; theoretically, poor academics may also augment the risk of obesity. Several studies have been listed that show the association between weight status and academic performance and behaviors. *(Appendix H)* One study in particular determined that obese children, according to school obtained health records, missed a mean of 4.2 days of school per month as compared to the 0.7 days per month of their healthy counterparts (Schwimmer, Burwinkle, & Varni, 2003). Researchers who analyzed more than 2 million grade school student FITNESSGRAM test results, found higher physical fitness achievement was associated with better school attendance rate (Welk, et al., 2010). The correlations were weaker for measures of body mass index, but the patterns were consistent. The reasons for absenteeism were not investigated but missed school days may subsequently lead to decreased school performance.

Use of Accelerometers to Measure Sleep/Physical Activity

An accelerometer is a motion sensor that allows body movements to be directly and continuously measured and quantified in natural settings. The use of acceleration for the measurement of physical activity allows the amount of movement intensity to be monitored. It is based on the principle that vertical acceleration is generally related to energy expenditure during locomotion. Intensity of activity influences physiological response. Combining frequency and duration with intensity of activity can provide a more detailed characterization of the activity. Accelerometers allow researchers to estimate the energy expended. Acceleration is the change in speed and position with respect to time and more directly reflects energy expenditure. Energy expenditure is a composite measure of physical activity that not only takes into account intensity but also body size. Accelerometry is based on the assumption that limb movement and body acceleration are theoretically proportional to the muscular forces responsible for the accelerations (Bouten, Verboeket-Van de Venne, Westerterp, Verduin, & Janssen, 1996). Energy expenditure can therefore be estimated by quantifying accelerations (Freedson & Miller, 2000). ActiGraph (ActiGraph, Pensacola, FL.) monitors have been the most studied motion sensors in children and adolescents. There is extensive evidence for good reproducibility, validity, and feasibility of the monitor in healthy children (de Vries, Bakker, Hopman-Rock, Hirasing, van Mechelen, 2006). The ActiGraph motion sensor has integrated circuitry and memory to provide a continuous recording of minute-by minute movement counts. These have been validated as an objective monitoring tool of children's physical activity in field and laboratory settings (Janz, 1994).

Quantifying physical activity in free-living children poses many idiosyncratic challenges. Physical activity dimensions (intensity, frequency, duration and type) pose serious objective measurement obstacles in this population. Many of the measurement terminologies reference adult activities. Moderate intensity is generally defined as activity requiring a rate of energy expenditure of 3-6 METs (metabolic equivalent of a task) with common task examples to include house work, walking, and gardening (Hendelman, Miller, Baggett, Debold, & Freedson, 2000). These descriptions reference activity levels of adults rather than the impromptu, sporadic activities of children. A natural variation in rate, intensity, and intervals of various activity types and events characterize the scope, magnitude, and tempo of physical activity in children (Welk, Corbin, & Dale, 2000). Loose definitions of physical activity recommendations tend to be convenient for public health policy but leave an uncertainty about the precise meaning of the guidelines, especially in a young population.

A contemporary systematic review of the health effects of physical activity on school-aged youth revealed a consensus that an accumulation of at least 60 minutes of moderate to vigorous physical activity on a daily basis is consistent with desired health and behavioral outcomes

(Strong, et al., 2005). Prior to this in-depth evaluation, the physical activity status of this population was reliant on fairly inconsistent guidelines.

In studies where physical activity patterns of youngsters were continuously and objectively monitored using accelerometers, few young children actually engaged in extended bouts of physical activity for fifteen minutes or longer. The sporadic bursts of physical activity characteristic of children's patterns of physical activity render it particularly difficult to capture data via self-report methods (Baquet, Stratton, Van Praagh, & Berthoin, 2007). This recall challenge is also enhanced by specific confines in a child's cognition, such as limitations to the concept of time, inability to accurately recall, and the distraction of emotion associated with unstructured play-time activities (Bailey, et al., 1995). Although sporadic bouts of activity are particularly difficult to capture with self-report questionnaires in children, the importance of accurately gathering information related to these bouts of activity has recently been acknowledged. Assessment of physical activity patterns in children has demonstrated a positive relationship between not only the intensity of the bouts of activity to fitness but also the interval between the bouts of activity to body fatness (Chu, Hu, Tsang, & McManus, 2005).

By objectively measuring physical activity and sleep with an accelerometer, recent research has added to our knowledge of the relationship and patterns between sleep and daily exercise. *(Appendix I)* With the use of an accelerometer worn for 24 hours, mean activity counts during the day were shown to be inversely related to sleep latency in seven year olds (Nixon, et al., 2009). Higher physical activity during the day as objectively measured with actigraphy decreased the time it took these children to fall asleep. Conversely, for every hour during the day spent in low activity counts, or sedentary behavior, sleep latency was increased by 3 minutes (Nixon, et al., 2009).

It has been widely assumed that physical activity is an important factor in the development of protection against obesity (Janz, et al., 2009). Yet, most studies in the United States suggest a secular trend toward declines in physical activity in youth over the past several decades (Pratt, et al., 1999). However, direct evidence of decreasing energy expenditure among children in recent years remains fairly elusive. There appear to be no clear trends documented in physical education throughout the past decade. Additionally, there is no data for after-school or daycare programs, which proportionately consume more of a child's free time. Data from 2001, however, do state that youth average only 8 minutes a day expending energy in some form of active transportation (Sturm, 2005). A prospective randomized trial was conducted to examine the potential health benefits of active modes of transportation to school in the fall and spring of fourth and fifth grade (Rosenberg, Sallis, Conway, Cain, & McKenzie, 2006). Accelerometers were used to measure physical activity; height, weight and skinfolds were also objectively measured. Results showed that boys who actively commuted to school had significantly lower BMI and skinfold values than boys who did not actively commute to school (Rosenberg, et al., 2006). There were no significant differences between active and nonactive commuter girls for either BMI or skinfolds (Rosenberg, et al., 2006). Reasons for the inconsistent results are not clear. Active transportation (walking, running, bike riding, etc.), however, does not appear to be a major source of physical activity for children. In short, physical activity associated with getting to and from school has decreased, yet simultaneously time spent away from home in school activities has increased.

Discrepancies have also been documented between nationally gathered statistics and direct observation in 3-5 year old children. A recent study that employed direct observation of preschoolers actually showed that after 290,000 thirty-minute segments of outdoor playtime surveillance, 89% of the physical activity witnessed was sedentary (Brown et al., 2009). Yet, pragmatic considerations often suggest self-report as the tool of choice. Consequently, current policy recommendation guidelines are not based on a substantial body of empirical evidence, but rather on a culmination of self-reports (Twisk, 2001). Epidemiological relationships based on objective measures may very well result in more precise recommendations for physical activity levels.

Most cross-sectional and longitudinal observational studies have suggested that youth of both sexes who participate in relatively high levels of physical activity have less adiposity than less active youth (Berkey et al., 2000; Eisenmann, Bartee, & Wang, 2002; Lazzer et al., 2003). However, this is often where the consensus ends. The empirical evidence linking physical activity patterns with obesity in youth remains contradictory and inconclusive (Patrick et al., 2004). The impact of physical activity on obesity has been investigated with conflicting results (DeLany, 1998). In a review of more than 100 studies of correlates of physical activity, only about one-half of studies among children from age three to twelve years found a relationship between physical activities and overweight as measured by body mass index (BMI) (Sallis, Prochaska, & Taylor, 2000).

Gaps in the knowledge of accelerometry led to the transpiring of a conference several years ago designed to address the issues related to motion sensor functioning, standards of monitor field use, and interpretation of accelerometer data (Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). Comparison between studies was accentuated as not appropriate secondary to the different commercial activity monitors. Sampling rates and measurement standards are considered proprietary and are not available to the public. The knowledge gap was narrowed by this conference with increased understanding of the use of accelerometry, but no clear consensus was reached on best practice recommendations. Although use of accelerometry to measure activity offers many improvements over self-report techniques, challenges remain. The factors and benefits related to the implementation of accelerometry were recently published. For the purpose of evaluating physical activity interventions in the field, sixty three participants were recruited from a subsample of a larger study. The purpose of the research was to provide a validity check on the seven-day Physical Activity Recall assessment. Implementation of best practice recommendations for accelerometry was utilized. Results showed that the accelerometer did capture and detect physical activity dimensions that were unreported with self-reports and recall and improvement and accuracy in physical activity measures were enhanced (Napolitano et al., 2010).

Many of the cross-sectional studies demonstrate a wide spectrum of results (Ekelund et al., 2005; Gazzaniga & Burns, 1993; Klein-Platat et al., 2005). A meta-analysis of thirty-one studies in children showed only 16 demonstrated a significant association between physical activity and weight status (Sallis, et al., 2000). The complex relationship between physical activity and adiposity depends on the method of measurement; more precisely, studies using objective assessment tools show stronger results (Rowlands, et al., 2000). It is important to note that these inconsistent study results are the consequence of various physical activity assessment techniques, to include subjective questionnaires, surveys, and reports. In a study involving forty-two 8 year old children, the negative relationship between visceral abdominal fat and physical activity were only evident through the use of accelerometers and not through the self-reported measures (Saelens, Seeley, van Schaick, Donnelly, & O'Brien, 2007).

Research and information are evolving as related to use of accelerometer measurements in sleep and physical activity. Secondary analysis of data from the European Youth Heart Study was examined using different measures of accelerometry-assessed physical activity. These activity dimensions were evaluated as they related to clusters of cadiovascular disease risk factors for dose-response relationships (Anderson et al., 2006). Thirty-three hundred 9 to 15 year olds were monitored for four consecutive days. The mean total of four skin-folds was used instead of body mass index since fitness was included in the outcome variables and fitness is expressed relative to bodyweight. This study had the advantage of indicating explicit graded negative association between cardiovascular risk factors (skin-folds and bodyweight) and physical activity. This is a pivotal study secondary to the implications and consequences of the risk factors. The sample size and availability of cardiovascular risk factors together with the objective monitoring of physical activity made this a strong, compelling study. The limitation of the measures of physical activity (swimming, cycling, load-bearing) were particularly applicable in this European population, though. Four days of physical activity monitoring may also be insufficient to assess a person's true pattern of physical activity. Accelerometry was used in another recent distinctly unique study. Two hundred and forty-four children recruited from a birth cohort were followed from age three to seven years (Carter, Taylor, Williams, & Taylor, 2011). These children were seen every six months, analysis data was gathered annually, sleep duration and physical activity were measured via motion sensor for five consecutive days and nights at four time points, and questionnaires were completed by the parents. Results from this longitudinal study showed that children who slept less had a significantly increased risk of having a higher BMI. Further adjustment for dietary intake and physical activity/inactivity weakened the relationship between sleep and BMI (Carter, Taylor, Williams, & Taylor, 2011). This study maintained an overall impressive retention rate over the four years in this New Zealand sample. Sleep and physical activity were both objectively monitored by actigraphy.

However, the accelerometer was placed on the trunk for both the daytime and nighttime monitoring. Assessment of sleep-wake patterns with accelerometry typically uses the wrist as the measurement site. The resultant consequence of this change in recommended standard is unknown.

Children's patterns of physical activity have been historically assessed by direct observation, questionnaires and heart-rate monitoring (Kohl, et al., 2000). Imprecise measures and lack of a gold standard for the specific quantification of energy expenditure of physical activity in children has hampered the development of universally acceptable and accurate field assessment techniques. Activity monitors (accelerometers) were developed in response to the lack of reliability of self-report measures, the intrusiveness of direct observation, and the complexity of heart rate monitoring. As the accelerometer-based monitors evolved, investigators validated and calibrated them in the populations of interest. Accelerometers have been validated against direct observations, heart rate monitors, self-report measures, and measures of energy expenditures (Janz, 1994; Welk & Corbin, 1998). They have been validated against indirect calorimetry and calibrated in terms of resting metabolism equivalents (METs).

Accelerometer-based activity monitors have been shown to be valid and useful devices for the assessment of children's physical activity (Puyau, et al., 2002). The monitor enables researchers to examine the duration of physical activity at varying levels of intensity. The high correlations between activity counts, activity energy expenditure, oxygen consumption, and heart rate confirmed in a controlled laboratory setting that the accelerometers strongly reflected energy expended in activity (Chu, McManus, & Yu, 2007; Puyau, et al., 2002).

Accelerometers have improved the assessment of physical activity by replacing the inaccurate reflections of self-reporting with the objective measurement of physical activity patterns and energy expenditure over extended time frames in free-living situations. The recent release of a triaxial accelerometer (ActiGraph GT3X: monitors, collects, and integrates acceleration from three planes) may offer an even stronger prediction of free-living energy expenditure than the uniaxial accelerometers (Ott, et al., 2000; Plasqui, et al., 2005). The triaxial accelerometer is able to recognize movement across the intensity spectrum as well as quantify activity during static or sedentary periods. The best, most comprehensive results are achieved when a triaxial accelerometer is used (de Graauw, de Groot, van Brussel, Streur, & Takken, 2010). It is designed to assess human movement and offer second by second measurements of activity. These motion sensors are capable of providing a means for quantifying overall movement over a period of days to weeks by capturing the intensity, frequency, and duration of movement. When the dimensions and patterns of activities are of interest, accelerometers are the recommended measurement tool (Rowlands & Eston, 2007). Research with another type of triaxial accelerometer demonstrated the ability of these motion sensors to quantify ambulation across the intensity continuum (Chu, et al., 2007). Accelerometers have become the preferred choice for continuous, unobtrusive, and reliable monitoring of human movement (Godfrey, Conway, Meagher, & O'Laighin, 2008). The ability to detect the subtle periods of inactivity is also of particular importance when analyzing levels of activity, movement, and cadence patterns in children. Additionally, three dimensional accelerometers provide a better evaluation of children’s free play activities since the anteroposterior plane as measured by the triaxial monitor is the main component of physical activity typical of children (Eston, et al., 1998; Oliver, Schofield, & Kolt, 2007). The capacity of the triaxial accelerometers to measure light intensity levels of activity as well as sedentary activities establishes a precedent for the accurate recording of circadian activity configurations.

Accelerometer measured physical activity represents a substantial improvement compared to self-report methods and parental proxy records (Bender, Brownson, Elliott, & Haire-Joshu, 2005). Comparison studies were conducted utilizing the objective data of the accelerometer, parent proxy records of children activity levels, and self-reports from the children. The parent proxy record was shown to be an invalid measure of physical activity levels in children between the ages of 5 and 12 years (Bender, et al., 2005). In addition, self-reports alone are now considered inappropriate in children younger than ten years of age due to their inherent difficulty in recalling activity behaviors, durations, and intensities (Sallis & Saelens, 2000). Questionable reported data and compliance accuracy were limitations of these gross estimations based on self-report. Since children tend to overestimate the duration and intensity of their physical activity, the reported activity levels were suspect of being grossly inflated (Pate, Freedson, & Sallis, 2002; Sallis & Saelens, 2000; Welk & Corbin, 1998). Self-reporting tends to overestimate vigorous activity and underestimate moderate to intense activity. However, prior to the use of any objective measures for physical activity dimensions, these estimations have been the foundation for the formulation of health policies and the establishment of health guidelines. The impact has been seen in invalid and incorrect physical activity guidelines and compliance assessments prior to 2000. The correlation between self-reports and objectively measured physical activity have been shown to be low (0.14-.053) (Sallis & Saelens, 2000). No actual consensus was arrived at relative to the age-specific physical activity recommendations for children until the more recent and objective use of motion sensors throughout this past decade.

An additional dimension of physical activity that can be evaluated through the use of accelerometers is the intensity of movement. In a large cohort of 5500 twelve-year-old children physical activity was measured using an accelerometer. Fat and lean mass and body mass index were also measured and correlated with the physical activity dimensions. A strong negative dose-response association between objectively measured physical activity and measures of fat mass and obesity, as measured by BMI, was realized. The strength of the correlation between physical activity and obesity was reported to be augmented with moderate and vigorous activity as opposed to simply total physical activity time (Ness et al., 2007). This is a cross-sectional correlation study; consequently no causality can be inferred. The data in this study does not adjust for social or demographic confounders, such as socioeconomic status. Additionally, the activity was monitored over a three to seven day period that may not have always included a weekend. The epoch used was one minute; consequently bouts of moderate-vigorous activity bouts could very well have been missed. Using this same birth cohort from the Avon Longitudinal Study of Parents and Children, despite what appeared to be high volumes of physical activity, few children actually met the recommended levels of sixty minutes daily of moderate to vigorous physical activity (MVPA) (Riddoch et al., 2007). It has been suggested that children may not only be under-performing sustained bouts of intense activity but are insufficiently active according to current recommended levels for health to achieve effective cardiovascular fitness (Riddoch, et al., 2007; Trost et al., 2002). Another cross-sectional study was performed with a relatively small group of fifty-six preschoolers (2 to 5 year olds) from a Women, Infants & Children (WIC) program. The use of motion sensors concurred that vigorous and very-vigorous activity were associated with lower odds of overweight men (Metallinos-Katsaras, Freedson, Fulton, & Sherry, 2007).

Actigraphy appears to be a viable method to correlate the dimensions of physical activity with sleep characteristics. It has been shown that data obtained from a wrist-mounted movement detector could be manually scored to distinguish sleep from wakefulness with a high degree of accuracy, as compared to polysomnography scoring (Cole, Kripke, Gruen, Mullaney, & Gillian, 1992). Very few studies have addressed the stability and reliability of actigraph measures across nights for individuals. Aggregation of sleep-wake variables necessitates at least seven nights to render a reliability estimate of .70 (Acebo, Sadeh, & Seifer, 1999). Since sleep plays an important role in the growth, development, and health of a child, it is essential to objectively determine parameters, implications, and correlations for the purposes of verifying evidence-based research and consequent optimal health recommendations (Mindell, Owens, & Carskadon, 1999). A complete account of precisely what sleep actigraphy in children is capable of showing and specifically how it can be recounted is lacking.

Actigraphy is a non-invasive longitudinal assessment method used to study sleep-wake patterns and is based on the fact that movement activity differs between sleep and wakefulness. Actigraphy is much less expensive than polysomnography (PSG), records limb movement, is a reliable and valid instrument for detecting sleep in healthy populations, especially in children (Ancoli-Israel, et al., 2003). In comparison to PSG, actigraphy has reasonable validity and reliability in assessing sleep-wake patterns in normal individuals with average or good sleep quality (Sadeh, 2010). Validation studies have found agreement rates between activity-based sleep-wake states and scoring with concomitant PSG and direct observation of 85-95% (Sadeh, Acebo, Seifer, Aytur, & Carskadon, 1995). In the final analysis, actigraphy only measures movements and not sleep per se. It is best at estimating total sleep time, and should always be accompanied by a sleep diary or log (Ancoli-Israel, et al., 2003). Sleep assessment based on subjective reports is the most commonly used method despite the restricted and biased knowledge that children and their parents have about their sleep (Sadeh, et al., 1994). Historically, pediatric sleep studies rely predominantly on questionnaires to verify sleep qualities and quantities (Chaput, et al., 2006; Chen, et al., 2006). Nocturnal PSG, however, is costly to record and score, may compromise a child's sleep, and gives little or no information on daytime sleepiness or napping. Additionally, sleep data obtained in a lab setting often does not correspond to information recorded from a home environment (Portier et al., 2000).

Actigraphy is sometimes used to obtain better estimates of quality and quantity of sleep but does not provide information particular to sleep staging (Sadeh, et al., 1995). Objective sleep data has been shown to consistently yield more accurate details than subjective sleep diaries (Chen, et al., 2006). Sleep assessment based on subjective reports is the most commonly used method despite the restricted and biased knowledge that children and their parents have about their sleep (Sadeh, et al., 1994)

Using accelerometers to objectively measure is not only expensive, but the data collected is dependent on the generation and type of accelerometer used. Use of an objective instrument, however, such as the accelerometer, suggests the ability to obtain a more detailed assessment of the combined physical activity variables (duration, intensity, and frequency). Recent reviews have concluded that accelerometers provide an objective and practical means of quantifying the amount and intensity of customary and habitual physical activity patterns in children (Reilly et al., 2008). They are useful for the objective assessment of frequency, intensity, and duration of physical activity (Rowlands, 2007). The magnitude of the relationship between activity and adiposity is strengthened when activity is objectively measured. Accelerometers provide objective, detailed measurements about physical activity in children. They can be programmed for various increments of time (10 – 60 seconds) and can be used over a relatively lengthy period of time (days) (Dencker et al., 2006). The accelerometer is currently the objective method of choice for measuring physical activity dimensions (Reilly, et al., 2008). However, to date, minimal attention has been directed toward standardizing this method of data collection, including placement of the monitor on the body (waist, hip, wrist), processing (epoch limits), and interpretation (threshold evaluations) (Freedson, et al., 2005). The results of activity monitoring studies can vary greatly depending on how the activity is measured and how it is interpreted. Physical activity in this dissertation research was objectively measured using the new triaxial activity monitor (ActiGraph; GT3X+; Pensacola, Florida). *(Appendix J)* Accelerometers have become the preferred choice for a continuous, unobtrusive and reliable method in human movement detection and monitoring (Godfrey, et al., 2008). The Actigraph is small, easy to wear, and is probably the most widely used of the accelerometers in physical activity research. It measures physical activity duration and acceleration (rate and intensity) patterns along three planes: anterior-posterior, mediolateral, vertical. *(Appendix K)* The three axis detections are combined to provide a triaxial vector magnitude count. The vector magnitude (also referred to as the activity index) is the square root of the sum of the squared counts from all three planes. Since the Actigraph is the most studied motion sensor in children due to its superior reproducibility, validity and feasibility, it has been proven to be a valid measure of physical activity in children, both in a controlled laboratory environment and during free-living (Trost, 2001). The Actigraph uniaxial (unidirectional) motion sensor was validated and calibrated against continuous six hour measurements of energy expenditure using room respiration calorimetry, activity by microwave detectors and heart rate by telemetry. Results certify these monitors have adequate validity and are useful devices for the assessment of physical activity in children (Puyau, et al., 2002).

Use of triaxial devices has been shown to confirm a more precise detection of walking intensities than uniaxial devices (Bassett et al., 2000; Eston, et al., 1998; Levine, Baukol, &

Westerterp, 2001). Since the daily activities of children predominantly consist of walking, this population-specific validation and reliability needs to be exploited for the assessment of their tempo. While it is true that most movements in the sagittal and frontal planes will also involve movements in the vertical plane, the three-dimensional output may provide a more stable indicator of overall body movement, especially in children. Validation studies with another relatively new triaxial accelerometer (RT3) have been performed across a variety of treadmill and unregulated activities against the criterions of oxygen consumption and body size (Rowlands, Thomas, Eston, & Topping, 2004). The RT3 (StayHealthy; Monrovia, California) has been shown to have good reliability and adequate validity as a measurement tool for physical activity in Caucasian boys (Rowlands, Thomas, Eston, & Topping, 2004; Powell & Rowlands, 2004). The triaxial accelerometer (RT3) can recognize ambulation across the intensity spectrum as well as quantify non-ambulatory or sedentary periods (Chu, McManus, & Yu, 2007). High correlations (r = .95) between active energy expenditure and metabolic cost in free-living conditions have been demonstrated with the RT3 accelerometer (Sun, Schmidt, & Teo-Koh, 2008). The RT3 validity has also been assessed during physical education lessons where a high correlation was demonstrated between the RT3 outcomes and the observed moderate to vigorous physical activity in school-age children (Scruggs, Beveridge, & Clocksin, 2005). The ActiGraph triaxial accelerometer (GT3X) and the StayHealthy triaxial accelerometer (RT3) both use an integrated circuitry (as opposed to three separate accelerometers) to assess activity on three planes. The comparable operational mechanisms are likely to yield analogous validation results. The RT3 accelerometer, however, is not as user friendly as the ActiGraph GT3X, particularly in research studies involving children, for a number of significant reasons. The RT3 does not have the battery life or memory of the GT3X. Activity cannot be recorded in small epochs (2 second epochs) for any length of time (greater than 24 continuous hours) with the RT3. The RT3 can only be worn as a waist clip-on and this was a disruptive place for children in the feasibility study to wear it. The downloading of data is more cumbersome and more tedious with less analysis programming ability. Additionally, the NHANES protocol for 2011 and 2012, stipulates that many of the 5000+ survey participants will wear an ActiGraph GT3X+ ambulatory monitor for 7 days to measure the amount and intensity of physical activity and sleep quality. This is a testament to the validity and reliability of the ActiGraph hardware and software products.

Pilot Study

A feasibility study using the new released ActiGraph triaxial accelerometer was conducted to test the use of this motion sensor for an extended period of time in an eight-year-old population. The monitor was worn in one of three randomly chosen sites (waist, wrist, and ankle) continuously for 7days / 24 hours per day. Activity intensities, frequencies, and durations and sleep durations, latencies, and efficiencies were objectively measured in 30-second epochs in this homogenous cohort (n=15) of eight-year-old children. This descriptive design also included qualitative surveys completed by the children, with the assistance of a parent, related to demographic characteristics, subjective recall of activities to supplement the objective data gathered by the motion sensors, and feedback on the experience of wearing the motion sensor 24 hours for 7 days. Findings related to the feasibility issues revealed that patterns of activities rendered from each site, the waist, the wrist, and the ankle were very similar. Monitor placement position did not influence the prediction of energy expenditure. According to our calculations using MANOVA (α = .05) there was no statistically significant difference in activity level patterns per position placement of the motion sensor ($F=60.66$, $df_1 =1$, $df_2 =12$, $p< 0.0001$).

These results were confirmed in a recently published study with a population of nursing facility residents (Rapp, Oliver, Bergstrom, & Cron, 2010). The mean, median, and standard deviation for activity frequency, intensity, and duration were recorded without significant difference on the ankle, wrist, and waist. All three sites were shown be interchangeable. These findings were also confirmed in a recent study, using uniaxial accelerometers (Kinder et al., 2010). These studies provide valuable information and data for researchers interested in capturing children's physical activity and sleep patterns simultaneously while in their natural settings.

For the purposes of consistency, comfort, and simplicity, the children's non-dominant wrist was used as the position for monitoring the daytime physical activity as well as the sleep in this study. According to the qualitative data gathered at the *End-of Study Questionnaire*, the children stated unequivocally that the wrist was the preferred site to wear the monitor based on comfort and lack of need to re-adjust. The non-dominant wrist is also the recommended site for analysis of sleep characteristics. Additionally, the thirty-second epoch added considerable detail to the data collected but the accuracy of the data analyzed in the pilot study was not increased. In order to put the data into the sleep analysis component of the software, it needed to be re-integrated into sixty-second epochs. Per this pilot study, the accelerometer was worn on the non-dominant wrist 24/7 and the epoch set at 2 seconds for the purpose of collecting the most data, in the smallest increments, to best appreciate the sporadic bouts of energy displayed by eight year olds. Most essentially, the feasibility pilot clearly demonstrated the ability of these new triaxial monitors to detect accurately the physical activity and sleep patterns in eight year olds and the ease with which this population could wear these monitors over an extended time period.

CHAPTER THREE

Methodology

This chapter addresses the methodological procedures that were implemented in the current study. Research design, sample, study variables, instrumentation, data collection, and statistical analysis procedures are discussed.

Design

This study utilized a correlational descriptive design to determine the relationship among objective dimensions of physical activity and sleep and a health indicator (weight status) and two psychosocial indicators (academic achievement as measured by performance assessment [standardized testing scores and teacher evaluations] and the academic behavior of school attendance). Quantitative and qualitative data were collected employing a cross-sectional, repeated measures design. Data was collected and reviewed per the instruments and protocol described, explained, and listed below.

Human Subjects Protection

Wayne State University (WSU) Human Investigation Committee (HIC) approved the protocol before any data was collected. The WSU Human Investigation Committee (HIC) Approval was obtained. (*Appendix L)* WSU HIC protocol guidelines were followed. The charter school superintendents and respective principals for each building also reviewed the study procedures prior to any recruitment and enrollment. The principal investigator did all enrollment and data collection procedures. The HIC approved study protocol was reviewed in detail with the appropriate school contacts, designees, and teachers. All questions were addressed and answered. Complete and detailed information was then sent home with the students for parental review and intended involvement. There were no stated potential risks to study participants. All enrollment was voluntary and withdrawal from the study at any time for any reason was explained as absolutely acceptable. This process was clearly explained to the participants and caregivers. Subjects were given a prorated gift card for early withdrawal to compensate them for time and effort. The research phone number was highlighted and given to all participants as a method of communicating with the investigator.

A numbered electronic list was kept for the purpose of tallying questionnaires, surveys, and exception logs while maintaining the confidentiality and identity of the participants. Accelerometers were identified by customized serial numbers that corresponded to the electronic list. Participant identification was made through this numbered sequence. The principal investigator and the research assistant were the only persons with access to the master list. The research assistant completed her HIC training and was instructed on the confidentiality protocol for this study. (*Appendix M)* The research assistant was included in the original HIC approval but was blinded to the details of the research study itself. The principal investigator collected all enrollment information and performed all data analysis. The demographic surveys and signed consent forms were kept in a locked file cabinet in a nursing research office. Accelerometers were immediately downloaded to locked computers in this office and the data analysis was confined to a secured location, a locked cabinet, in the locked research office, as stipulated in the HIC protocol summary. Computers and accelerometers were locked throughout the course of the study and throughout the data analysis.

Sample

A convenience sample of eight year olds in the third grade at one of two Detroit charter school systems was used to obtain the population for this research. Access to the third grade classrooms and the third grade teachers was arranged prior to the start of the school year. The recruitment process was then initiated after the HIC approval was obtained.

Charter schools are public schools run by independent entities sponsored by state-approved organizations. The voluntary enrollment structure is intended to make charter schools more accountable for student achievement. As a result, charter schools are granted some level of autonomy and freedom from certain local and state regulations. Accordingly, charter schools set their own educational programs and methods of operation with oversight from their school board and trustees. Since charter schools are state-supported public schools they receive funds on a per-student basis from the state and do not charge tuition. The two charter school systems used in this research consisted of three distinct campus locations, located geographically within a one mile radius of each other. One of the charter school systems had two elementary school campuses. All three campuses have been launched within the past 10 years and have grown exponentially due to disappointments in and closings of many of the city's public schools.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were established with the target goal of clearly correlating health and psychosocial indicators. A homogenous sample in similar settings was sought. Consequently, criteria were set to include only students that would develop that purpose. Likewise, Students were excluded that may have a preexisting situation or trait that would add inaccuracy to the correlational associations sought. Inclusion criteria included third grade students currently enrolled in one of the participating charter schools, eight years of age, male or female, and English speaking. A consistent caregiver and/or parent were required during the seven day study period. It was necessary that the child be willing to not only wear the accelerometer for 24 hours a day for seven consecutive days, but they were also requested to persistently and completely finish an exception log for each 24 hour period during their designated week. Exclusion criteria included co-morbidities that impacted activity and sleep cycles, to include musculoskeletal disorders, obstructive sleep apneas, and parasomnias. Excluded from the study were any third grade children who were not eight years of age at the time the monitor was scheduled to be placed on their wrist.

Sample Size

Based on a formulation of 80% power, a critical effect size of .30, and a significance level of 0.005 (adjusted for at least 10 outcome variables), a sample of 125 subjects was deemed sufficient to address the study research questions. The Gpower computer software (Version 3.0.10) was used to calculate the required sample size. If, however, we did not adjust for multiple outcome variables and used an alpha = 0.05, then a sample size of 67 would have been sufficient (Faul, Erdfelder, Lang, & Buchner, 2007).

Recruitment

Recruitment consisted initially of letters and brochures that were sent in the student's home folders. All three charter schools used the same form of written communication process between the school and home. In addition, robo calls were sent out by the third grade teachers as a form of reminders to the parents. After the first wave of enrollment, a second flier was sent home to the parents again via the home folders. The total population of third graders in all three schools totaled about 180 students. Seventy-five children returned signed consent forms. Twenty-five percent of these children were either eliminated because they did not meet criteria or dropped after enrolling for various reasons. Once the difficulty and challenges with recruitment and retention were appreciated sample size was revisited. Upon review of prior like studies, the effect size was change to 0.5 or large. A sample of forty-seven was then needed. Fifty-five students completed the study.

Recruitment was a joint cooperative effort on the part of the school administrators, the third grade teachers, and the principal investigator. The population of eight year old students recruited for this research study attended one of three charter schools in the city of Detroit. Represented in this cohort was a homogenous low socioeconomic group of predominantly African American eight-year-olds. All recruitment and enrollment and data analysis was done solely by the principal investigator. An oral script was read for the sake of consistency to the participants at their first study visit. (*Appendix N)* Emphasis was placed on the importance of the monitor, its sole purpose of collecting data, and its expense. Based on information and feedback from the feasibility study, compliance issues, care of the monitors, survey information, and diary use was addressed.

Setting

Two Detroit charter school systems were used to obtain the population for this research study. The school campuses were geographically in close proximity. This logistically involved three separate locations since one of the charter schools had two elementary school campuses. The similar socioeconomic and cultural composition of these schools (natural existing social units) lent to the homogenous characteristic of the cohort. The population of children was low socioeconomic and predominantly African American.

Major Study Variables and Measurement

The variables of interest for this study fell under two major constructs: health indicators and psychosocial indicators. The individual level health indicators chosen for this particular research were physical activity dimensions, sleep characteristics, and weight status. The community level psychosocial indicators selected included academic achievement, both standardized tests and teacher evaluations, and the academic behavior of school attendance. *(Appendix O)*

Physical Activity

For purposes of this study, physical activity was defined as any bodily movement produced by skeletal muscle that results in movement and energy expenditure (Caspersen, 1989). Physical activity was measured with an accelerometer. Accelerometry is a technique that allows body movement to be directly and continuously measured and quantified in natural settings. An accelerometer is a motion sensor that provides raw data in the form of movement counts. The conversion of this raw data from these techniques into different outcome measures is a critical part of the processing of physical activity data. The dose of physical activity or exercise required to affect a particular health benefit response basically varies along four dimensions: frequency, intensity, duration and type of activity. Consequently, the characteristics of physical activity were measured quantitatively in four dimensions: intensity frequency, intensity ranges, intensity duration, and intensity bouts. In addition, energy expenditure was converted to age-specific METs to assist in completing the quantification of the physiologic response to activity.

Table 3.1 Accelerometer Counts per Age-specific METs for Eight Year Olds

< 3 METs	Light activity	< 800 accelerometer counts (0-799) per minute
3 METs to < 6 METs	Moderate activity	< 3311 accelerometer counts (800-3310) / min.
>6 METs	Vigorous activity	≥ 3311 accelerometer counts per minute

Clinimetric properties obtained in a certain age group cannot be generalized to other age groups because of the differences in their physical activity pattern and anthropometrics (Stone, Esliger, & Tremblay, 2007).

Sleep Characteristics

For the purposes of this study, sleep was defined as a reversible behavioral state of perceptual disengagement from the environment in which there is a decrease in bodily movement and lowered energy expenditure cost (Carskadon & Dement, 1989; Tremblay, et al., 2007). Polysomnography (PSG) is considered the 'gold standard' by which data pertaining to sleep quality and quantity can be objectively determined (Quan et al., 2003). Actigraphy is an objective measure that allows evaluation of activities during sleep that would generally be missed by parental observation alone (Sadeh, et al., 1994).

Sleep characteristics of duration, and number and duration of nighttime wakenings were measured with wrist actigraphy (ActiGraph; GT3X; Pensacola, Florida). The new triaxial activity monitor was worn around the non-dominant wrist, attached with cloth wrist band. During daytime hours the recordings obtained physical activity counts and during nighttime hours, the recordings obtained the listed sleep characteristics. The sleep data in this research study was supplemented on the *Exception Log.* The *Exception Log* is simply a small spiral notebook that the child kept on his/her person to jot down events that may render unexplained spikes of activity. The child was also asked to write down the time he/she went to bed to finally go to sleep and the time he/she got out of bed for the final time in the morning.

Weight Status

Weight status was defined as the category of measured heaviness of the participants and was measured by body mass index (BMI). The BMI was computed from the student's measured weight and height. It was calculated as the weight in pounds divided by the height in inches squared, times 703. BMI was also rechecked for accuracy by using the *Child and Teen BMI Calculator* on the CDC website. The BMI-for-age percentile is used to interpret the BMI number in children because BMI is both age-and sex-specific for children. Table 3.2 shows the CDC percentile range with corresponding BMI per gender for eight year old children.

Table 3.2 Weight Status Category Percentile Range

		BMI 8 YEAR OLD GIRLS	BMI 8 YEAR OLD BOYS
UNDERWEIGHT	*< 5th percentile*	< 13.6	<13.8
NORMAL WEIGHT	*5th to < 85th percentile*	13.6 to < 18.2	13.8 to < 18.0
OVERWEIGHT	*85th to < 95th percentile*	18.2 to 20.6	18.0 to 20.0
OBESE	*≥ 95th percentile*	≥ 20.6	≥ 20.0

These criteria are different from those used to interpret BMI for adults, which do not take into account age or sex. Age and sex are considered for children and teens for two reasons. First, the amount of body fat modifies with age. Secondly, the amount of body fat differs between girls and boys. The CDC BMI-for-age growth charts for girls and boys take into account these modifications and allow translation of a BMI into a percentile ranking for a child's age. The body mass index (BMI) was calculated from height (without shoes) measured with a wall stadiometer (QuickMedical, Issaquah, WA) and weight (without shoes) obtained from a calibrated digital foot scale (QuickMedical, Issaquah, WA). *(Appendix P)* Clothing was fairly well standardized since all children wore uniforms. The measurements were made without shoes, jackets, or sweaters. Each measure was obtained three times and the mean of the readings was calculated and used. A QuickMedical Travel Measuring Kit has a capacity of 350 pounds, precise to a tenth of a pound with a large platform and easy portability.

Academic Achievement and Academic Behavior

The psychosocial indicators of academic achievement and academic behavior are defined as measures that impact the success of a student in school. The psychosocial indicator of academic behavior was defined as a reflection of school participation and was measured by school attendance records. The number of absent/sick days from the start of the school year per total number of school days was requested from the school.

Academic achievement was measured through recall ability as scored in the standardized Michigan Educational Assessment Program (MEAP) (October 2010) and the tally of teacher semester evaluations or grades. MEAP scores were used as an objective assessment of academic performance in these eight-year-old children and obtained from the school with the explicit consent of the subject and parent.

Scores and assessments rendered by teachers are typically the grades most available for data collection and research in large-scale surveys. However, they may be biased, depending on the quality and psychological state of the teacher and his/her ability to make such appraisals. A comparison of the standardized test and the more subjective scores rendered by teachers adds to the insight, implications, and analogy of these two evaluation methods. A tally of the teacher marks and ratings were averaged for the semesters. Again, these individual scores were used with the approval of the subjects and parents, in cooperation with the school district.

Extraneous Variables

Objective measures of physical activity were supplemented by data received from a questionnaire, a survey, and a diary/log. An *Exception Log* (spiral notebook) was given to the students with instructions to itemize various activities throughout the course of the study. Much individual freedom was assumed with this particular set of instructions. An investigator developed *Demographic Survey (Appendix Q)* was completed by the students at the beginning of the study. This survey included inquiries on gender, date of birth, race, living arrangements with parents, educational status of parents, number of siblings in household, number of meals eaten at home or out, number of meals eaten with family, playtime activities, frequency of playtimes, and hours of sedentary activities. An *End of Study Questionnaire (Appendix R)* was completed by the students at the conclusion of the study for the purpose of obtaining feedback on the experience.

The subject and variables at hand concentrate on the relationships among the objective measures of physical activity, weight status, measured sleep characteristics, academic achievement and academic behaviors. Healthy outcomes support the associations between types of activity and behavioral adaptations. The focus of this research was limited to the implications and interactions of the objectively measured variables cited. It is undeniably evident that diet and behavior modifications accentuate many health outcomes but these factors were not the essence of this research. A demographic survey was completed by the participants to capture some of the information relevant to family habits related to nutrition, behaviors, socioeconomics, and daily medicines. The subjects were requested not to make any significant changes in their eating or behavior habits during the course of the study. The concentration of this research was the associations of the objectively measured variables, while holding other variables as constant as possible, in an effort to better isolate and appreciate the measured relationships.

Additional confounding variables and situations that may impact the integrity of the research were identified and participants' data was considered on an individual basis but analyzed cumulatively in aggregate form. Unexpected conditions or circumstances may include seasonal illness, family challenges, or school difficulties and were considered individually.

Data Collection Procedure

Third graders who for the first time took the MEAP test in October were asked to wear an accelerometer around their non-dominant wrist during daytime hours and nighttime hours for one continuous week. Third graders are required under the federal No Child Left Behind Act (NCLB) of 2001 to be assessed in the subject areas of math and reading. These untimed, student-paced tests are scheduled every October in Michigan and typically consume about four hours of time over the course of three school days. Permission was sought from the students (oral assent) and parents (signed consent form) for the release of their individual MEAP scores from the school as well as their attendance records and teacher evaluations and grades.

The study brochure and consent form were sent home to the third grade parents with the children in their home folders. This was the accepted weekly form of communication with the parents in each of the schools. According to the administration and facility at each respective school, this was a very effective method. Responses from the parents were usually complete and timely. The parents were encouraged to read the consent form and brochure and send the signed consent back to the school if they were in agreement with allowing their child to participate. Included in the consent form, in addition to permission to allow the child to wear the accelerometer 24 hours a day for 7 days, was the permission for the release of the individual MEAP scores, grades from the teacher, and the child's attendance records from the start of the academic school year.

The third grade teacher received the consent forms from the students and notified the principal investigator when several consent forms had accumulated. The principal investigator made arrangements to come to the school at a mutually agreed upon time to enroll cohorts of third graders (5-9 students at a time depending on the number of participants and the number of available monitors). Compliance was fostered in the pilot feasibility study when friends were enrolled together and wore the monitors ‘together’. A follow-up phone call was always placed to the parent/guardian after placing the monitor on the child’s wrist to confirm understanding of the research study, enlist continued support, reinforce compliance in study protocol, and complete the unknown or unanswered questions on the *Demographic Survey*.

All enrollments were performed in a private room on school premises to promote neutrality of a meeting place. The inclusion and exclusion criteria were satisfied, discussions entertained, and questions answered. The oral assent was presented in a non-threatening manner using a consistent oral assent script. The *Demographic Survey* was initially attempted and completed by the students with follow up phone calls to parents/guardians for added clarifications. The body mass index (BMI) was calculated from the measurement of the height and weight. The initialized accelerometer was attached to the non-dominant wrist. The accelerometer was set to record activity counts in 2 second epochs over twenty-four hours for seven consecutive days. The student attached the monitor to their wrist with an adjustable cloth watch band. Introduction and instructions on use of the *Exception Log* (small spiral notebook used for recording time to bed and time out of bed and any times the monitor was removed) was explained individually to each child. The *Exception Log* was dated to coincide with the study period and carried with the subject throughout the week. A brightly colored sticker was adhered to the front of each notebook with the principal investigator's name and research phone number. The children were encouraged to call with any and all questions. Care of the monitor was reinforced. The site of the accelerometer was marked with permanent ink to designate the precise position on the body/wrist for consistency in reattachment. A return demonstration of monitor application confirmed comprehension and understanding. Reinforcement was given to the child on the importance of wearing the motion sensor in the same way and same spot 24 hours a day with removal only for water activities (swimming or bathing). Questions about the procedure were answered to the students' satisfaction by the investigator prior to departure. Participants were encouraged to contact the investigator if they have any unforeseen concerns and questions.

Children returned to the meeting room on the school's campus at a predetermined arranged time each week 7 days after the start of data collection with the accelerometers still attached and the *Exception Log* appropriately completed. The PI reviewed the *Exception Log* for thoroughness and legibility. The children then had the individual and private opportunity to provide additional feedback, comments, and concerns to the investigator by completing the *End of Study Questionnaire.*

The objective monitoring of physical activity and sleep was conducted over the span of seven consecutive days, twenty four hours per day, with the exception of water sports only. The GT3X ActiGraph, a small triaxial monitor collected the physical activity dimensions and sleep actigraphy data. The *Exception Log* was explained as a supplement to the accelerometer. The psychosocial indicators of academic achievement (MEAP scores and teacher grades/evaluations) and the academic behavior (attendance) was collected at the end of study period when available from the school districts. Through permission obtained on the consent form, the standardized MEAP scores were collected from the schools. Individual teacher grades/evaluations for the current school year were gathered, coded, and averaged. Attendance records were submitted per the individual school buildings.

The objective monitoring of sleep in this study focused specifically on the characteristics of night time sleep duration, the number and duration of wake episodes at night. Sleep duration in this research was determined from the objective renderings of a triaxial accelerometer. The eight year old subject participants were not consistently reliable record keepers when asked to record the time to bed at night and the time out of bed in the morning. The exact time to sleep was designated as the beginning of a series of zero counts on the motion sensor. Sleep start time was defined as at least three consecutive minutes of sleep and the sleep end time was defined as the last five consecutive minutes of sleep (Acebo, Sadeh, Seifer, Tzischinsky, Hafer, & Carskadon, 2005). This method proved to be the most reliable process for determining precise sleep times in this sample. Time in bed as reported by parents proves to underestimate sleep duration as compared to objectively measured actigraphy (Nixon, et al., 2008).

Compensation was given to the school district for their time and cooperation in the form of information sharing and health curriculum classes. The participants all received a $20 gift card to Target upon receipt and safe return of the sensor monitor. In addition, every student who participated in the study was entered into a drawing for an iPod that was raffled off at the end of the research period.

At the completion of the study recruitment, the third grade teachers agreed to complete the student's evaluations and grades, MEAP scores from the state, and the attendance record. A master list was generated with the student's name and the identification number assigned to their monitor. The identification number was also used to identify each child's corresponding *Demographic Survey*, the *End-of-Study Questionnaire*, BMI, and academic profile. The master list was initiated by the PI and maintained by the PI until the end of the enrollment period. Once enrollment was completed, the master list was sent to the study Research Assistant (RA) until the grades, MEAP scores, and attendance records were ready to be inputted. Subsequently, the PI had access to only the list with the ID numbers for the remainder of the study. The RA sent the list to the teachers who filled in the MEAP scores, grades/evaluations, and attendance records. The completed form was returned to the RA who removed the student name column and sent the list with number identification only to the PI for analysis. *(Appendix Q)*

Data Analysis

Descriptive statistics included measures of central tendency and dispersion. These statistics are used to describe the sample, the physical activity dimensions, sleep characteristics, body mass index, and psychosocial indicators. The circadian configuration of objectively monitored activities has been studied for insight into activity-sleep patterns and significance of subsequent conversions to energy equivalents through use of the ActiGraph software program, ActiLife. Use of the ActiLife analysis software (ActiGraph product) enabled and assisted with the complexities of evaluation of the accelerometer data as it related to the dimensions of physical activity and sleep characteristics. The ActiLife5 desktop analysis software suite is compatible with all ActiGraph research activity monitors and was used to configure the devices for data collection, to download and view, and to process the collected activity data. ActiLife5 data can be easily exported or converted other analysis programs (SPSS). This software allowed for batch data scoring, result graphing, sleep scoring, and data comparison to national standards (NHANES).

Information was supplemented with data from the submitted *Exception Logs*. The *Demographic Surveys* and *End of Study Questionnaires* were qualitatively tallied according to themes. Themes were organized, summarized and processed accordingly. This information was recorded and tallied and used qualitatively to compliment and expand upon the quantitative data gathered from the accelerometers.

The standardized MEAP scores and grades/evaluations assigned by the teachers were compared for consistency of pass-fail outcomes. The grades/evaluations rendered by the teachers were numerically coded, 0 - 1 for Fail - Pass. Pass–Fail was assigned to encourage consistency of scoring between schools and to support ease of qualitative analysis. Pass-Fail was determined according to several methods, either per letter grade, per evaluation narratives from the teachers, or, when necessary, per conversations with the teachers. Standardized test scores (MEAP) were grouped according to designated categories. Attendance records were calculated according to number of days of absences as well as percentage of total allotted school days absent.

The Statistical Package for the Social Sciences (SPSS) version 19 was used to analyze the data. Data analysis began with preparatory activities such as the treatment of missing data, identification of outliers and other such data cleaning tasks. A detailed descriptive analysis of all quantitative data was performed, involving the summarization of data and the use of inferential and graphical exploratory data analytic techniques. The research questions were statistically analyzed as follows:

1. What is the objective pattern of physical activity and sleep over the week in this cohort of eight year olds living in a low socioeconomic urban area?

   Analysis: Descriptive statistics was used to characterize the distributions including measures of central tendency (mean and median) and dispersion (range, variance, standard deviation) for continuous variables and frequency distributions of the categorical variables.

2. What is the relationship between patterns of free-living (unstructured) physical activity dimensions and objective sleep characteristics in a cohort of eight-year-old children?
3. What is the relationship between patterns of free-living physical activity dimensions and the weight status as measured by body mass index (BMI) in a cohort of eight year old children?

4. What is the relationship between patterns of free-living physical activity and the psychosocial indicators of academic achievement and academic behavior in a cohort of eight-year-old children?

   Analysis: To address Research Questions 2, 3, & 4, if the parametric assumptions were met, Pearson correlation coefficient was utilized to determine the relationship between variables measured on ratio or interval scales. If parametric assumptions were not met, the Spearman correlation analysis was performed.

5. Are there differences in physical activity and sleep variables between those who passed and those who failed school reading and mathematics?

   Analysis: Two sample independent t-tests were used to determine the difference in physical activity and sleep variables between those who passed and those who failed reading and mathematics?

6. To what extent does a linear composite of sleep characteristics, weight status, academic achievement, and academic behavior have a relationship with a linear composite of physical activity in a cohort of eight-year-old children?

   Analysis: Canonical correlation analysis was used to determine the correlation between the two linear composites of demographic variables and physical activity variables. Canonical correlation is a multivariate statistical model that facilitates the study of interrelationship among sets of multiple dependent variables and multiple independent variables.

CHAPTER FOUR

Results

The subject demographics and findings related to the study variables will be presented in this chapter. The quantitative results from the accelerometers and the qualitative results from the *Demographic Survey* and the *End of Study Questionnaire* will be explicitly laid out in tables. Following the sample demographics per each research question will be addressed with the appropriate statistical methods and presented in table form. Data was gathered from a total of fifty-five 8 year old third graders at three urban charter schools.

Sample Characteristics

Seventy-five children were screened for this study after returning signed consent forms from their parent(s). Four children were eliminated prior to wearing the monitor because they did not meet the age criteria. There were a number of reasons for eliminating or disqualifying some of the children and/or their data after enrollment. One of the monitors was lost despite major efforts to retrieve this costly item. One of the children returned the monitor after 24 hours stating that his father was concerned that there was an audio component to the monitor and did not want his privacy invaded. Another one of the monitors was accidently showered and permanently water damaged. Three monitors had battery malfunctions and did not render the required minimum of 5.9 days and nights of data. Additionally, eight children were dropped from the study because they did not actually wear the monitor for at least 20 hours / 24 hour day. Lastly, two of the children were excluded from the study secondary to imminent truancy charges and a sudden school transfer. Consequently, a total of 55 children met the inclusion criteria and successfully wore the monitors for the required time, and rendered usable data. The majority of children were extremely compliant with the instructions given for wearing the monitor and readily used the study phone to contact this investigator with questions or concerns. Three of the 55 children were prescribed inhalers for their asthma. No activity restrictions or recent exacerbations were reported by their parents. Thus, these three children were included in the study.

Personal characteristics of the sample are presented in Table 4.1. All of the participants were eight-years-of-age at the time they wore the monitor. The mean age of the sample was 8.7 years (± 0.26) with an inclusive range of 8.0 to 8.9 years. Fifty-two of the 55 (95%) children were African American. The remaining three (5%) considered themselves "mixed", meaning that one of their parents was African American and the other parent was either white or Latino. Thirty-five (64%) of the population were female and twenty (36%) were male.

Table 4.1 Personal Characteristics of Sample (n=55)

Characteristics	**Number (%)**
Race	
AA*	52 (95)
Mixed	3 (5)
Gender	
Girls	35 (64)
Boys	20 (36)

* African American

Table 4.2 presents ecological characteristics of the sample. A question on the *Demographic Survey* that elicited much discussion inquired about the child's number of siblings, particularly as it related to half-brothers and half-sisters. A phone call home was required to clarify two item answers on the *Survey*; the actual number of siblings and the highest educational level of the parent(s). Twenty seven (49%) of the children lived with only one parent and the remaining 28 (51%) lived with both parents. None of the children knew the amount of schooling their parent(s) had completed. As validated from phone calls to the homes, 25 (46%) of the parents completed some portion of college or a trade school; 26 (47%) ended their formal education with a high school degree; the remaining four (7%) did not complete high school.

Nine (16%) of the children reported someone other than a parent stayed with them during after school hours, most usually a grandparent. The number of siblings as clarified by the phone call to the parent(s) ranged from zero to nine with the mean number of 3.2 (± 2.3) siblings in the home.

Table 4.2 Ecological Characteristics of Sample (n=55)

Characteristics	**Number (%)**
Parents living in home	
Single	27 (49)
Both parents	28 (51)
Educational level of parents	
College/trade school	25 (46)
High school	26 (47)
Grade school	4 (7)
Usual after school caregiver	
Parent	46 (84)
Other person	9 (16)

School Attendance

Table 4.3 displays the school attendance record and the factors involved and implicated in this record. Absenteeism is a substantial concern and active issue in these particular charter schools. Tardiness and partial day attendance are also areas of high delinquency in these school systems according to the teachers and administration. Although partial day absenteeism, tardiness, and time spent in the "nurse's office" were not part of this study's data collection, it is noteworthy to mention that record-keepers from all three schools concurred these instances of lack of classroom attendance occurred more frequently than they were able to accurately track. Attendance data was tallied after day 144 of the school year, thus a partial school year. Total Michigan days per school year equate to 180 days. The mean number of absent days for this sample was 13 (± 5.8) days (9%) with an inclusive range of 0-39 days. According to administration and third grade teachers, absenteeism is impacted by two predominant justifications, illness and inadequate transportation. Three (5%) of the children used asthmatic inhalers on a fairly regular basis. The mean number of absent days for these children with asthma was 6.7 (± 4.5) days (5%) with an inclusive range of 2-11 days. Active transportation is arranged per individual student by the caregiver/parent. Charter schools do not qualify to participate in the public school bus systems. Fifty-two (95%) of the children were regularly taken to school in private vehicles. Three children (5%) admitted to occasionally walking to school. These transportation arrangements often proved to be very unreliable thus adding to the truancy issue.

Table 4.3 Attendance (n=55)

	Mean (SD)	**Percent**	**Inclusive Range (Min-Max)**
Absent days (144 total school days)	13 (5.8)	9	0-39
Use asthmatic medications* (n=3)			
Absent days	6.7 (4.5)	5	2-11

* Used inhalers infrequently (1-3 times per week) according to the parents

Mealtime Habits

Table 4.4 presents the mealtime habits of these eight-year-olds. All of the participants who wore a monitor qualified for the school lunch program. Six (11%) of the children took advantage of the free breakfast at school. To qualify as eligible for the school lunch program for the period of July 1, 2010 to June 30, 2011, the socioeconomic level of these children was at or below 130 percent of the poverty level. Thirty-three (60%) of the children stated that they ate their evening meal at a table with other family members. Twenty-two (40%) of the children reported eating dinner alone or in front of a media screen, such as a computer or a television.

Table 4.4 Mealtime Habits (n=55)

Habits	Number (%)
Qualified for school lunch program	55 (100)
Ate breakfast at school also	6 (11)
Ate evening meal w/family	33 (60)
Ate dinner alone or in front of media screen	22 (40)

Daily Activity Patterns

Physical activity routines and patterns are reported in Table 4.5. The children were also asked to circle the activity or activities that they most often participated in when they had outside free playtime. These activities were classified as active or passive recreational activities. Thirty-eight (69%) claimed that the majority of their outside play time was spent in active play while 17 (31%) merely stood around and/or socialized. Twenty (36%) children reported going outside to play on a daily basis, while 35 (64%) of the children reported not going outside to play regularly. Availability and frequency of recess periods was sporadic, contingent on the weather and ultimately the decision of individual teachers to go outside to designated, secured areas. Cumulatively, 32 (58%) of the children from the three charter schools cited that they never went outside for recess. Although each of the schools had physical education classes for the children, these classes lasted only 6-8 weeks per academic school year. Twenty-eight (51%) admitted to more than 5 hours of screen time per evening, most frequently in the form of television. Twelve (22%) of the children stated that they had between 2 and 5 hours of screen time per night while 15 (27%) related that their screen time was limited to less than 2 hours per evening.

Table 4.5 Physical Activity Routines and Patterns (n=55)

Routines	Number (%)
Play activity	
Active: run, play ball, ride bike	38 (69)
Passive: walk around, hang out, sit	17 (31)
Play frequency	
Everyday	20 (36)
Not everyday	35 (64)
Recess frequency	
Never	32 (58)
1-3 times a week	23 (42)
Hours of screen time per day	
>5 hours	28 (51)
2-5 hours	12 (22)
<2 hours	15 (27)

The physical activity dimensions were objectively calculated through the use of the ActiGraph software analysis. The activity count parameters were inputted according to the age-specific calculations from the Freedson equation. The light, moderate, and vigorous activity classifications were obtained by solving the prediction equation for eight year olds according to the universally accepted MET index categories (< 3 METs = light activity; 3-6 METs moderate activity; >6 METs vigorous activity). The physical activity intensity bout that is related to improved health outcomes is the moderate to vigorous intensity activity bout (Jakicic & Otto, 2005; Strong et al., 2005). It is the moderate to vigorous activity bout that is of interest in this research. The accelerometer counts were also recorded in a triaxial sphere as well as a uniaxial sphere, thus documenting the activity index as well as steps for each participant.

Physical activity dimensions for this sample are presented in Table 4.6. Of the physical activity during daytime hours, a mean of 86.36% (± 3.78) was registered as light intensity activity, 12.93% (± 3.53) was considered to be moderate intensity activity, and 0.7% (± 0.75) was vigorous intensity activity according to the triaxial accelerometer. Moderate-vigorous activity bouts lasting a minimum of five minutes with up to a one minute drop averaged 2.3 (±0.6) per day and lasted on average 10.45 (± 1.05) minutes per day. The mean number of steps/hour during daytime hours was 733 (± 125) steps. Steps per hour ranged from 465 to 945. The mean number of steps per day during the daytime hours was 10999 (±The mean vector magnitude (activity index) was 98335 (± 19368) counts per hour during daytime hours. Vector magnitude counts ranged from 56453 – 132622 per hour. Physical activity dimensions per gender are presented in Table 4.6a. Per t test analysis, no significant activity dimension differences between genders wass seen in this cohort of eight year old children.

Table 4.6 Physical Activity Dimensions (n=55)

Dimensions	**Mean (SD)**	**Inclusive range (Min - Max)**
Activity Intensity (percentage of activity/day)[a]		
Light	86.36 (3.78)	80.48 – 96.29
Moderate	12.93 (3.53)	3.22 – 18.43
Vigorous	0.70 (0.75)	0.13 – 5.54
M-V Activity Bouts (number/daytime hours)[b]	2.33 (0.6)	0.50 – 3.20
Length of Activity Bouts (in minutes)(minutes)	10.45 (1.05)	8.08 – 13.81
Steps per hour (number)[c]	733.28 (125)	464.55 – 944.84
Steps per day (number)	10999.19 (1879.51)	6968.25 – 14172.60
Vector magnitude (counts)[d]	98334.69 (19368.48)	56452.99 – 132622.40

[a] *Count range calculated per Freedson age-specific-equation: Light activity 0-700 counts, Moderate activity 800-3310 counts, Vigorous activity > 3310 counts*
[b] *Moderate – Vigorous Activity bouts: 5 minute bouts with 1 minute drop for counts 800-3310*
[c] *Horizontal axis only; functions as a pedometer*
[d] *Square root of each axis squared and summed; activity index*

Table 4.6a Physical Activity Dimensions per Gender

Dimensions	**Gender**	**N**	**Mean (SD)**	***t value***	***p value***
Light Intensity Activity	*Boys*	20	86.01 (4.49)	-.52	.61
	Girls	35	86.56 (3.37)		
Moderate Intensity Activity	*Boys*	20	13.04 (4.18)	.17	.86
	Girls	35	12.87 (3.17)		
Vigorous Intensity Activity	*Boys*	20	.95 (1.14)	1.46	.16
	Girls	35	.56 (.32)		
M-V Activity Bouts	*Boys*	20	2.26 (.70)	-.61	.54
	Girls	35	2.36 (.51)		
Length of Activity Bouts	*Boys*	20	10.12 (1.32)	-1.75	.09
	Girls	35	10.63 (.83)		
Steps per day	*Boys*	20	10984.67 (2210.40)	-.04	.97
	Girls	35	11007.43 (1697.07)		
Vector magnitude counts	*Boys*	20	97751.94 (21308.88)	-.17	.87
	Girls	35	98667.6884 (18486.47)		

Table 4.7 displays the physical activity dimensions with and without reported recess times per week. For those children who reported an occasional recess (3-5 times per week), a mean of 85.01% (± 3.72) of the daytime hours was recorded on the accelerometer as light intensity activity, a mean of 14.24% (± 3.55) of the daytime hours was recorded as moderate intensity, and a mean of 0.75% (± 0.36) of the daytime hours was recorded as vigorous intensity activity. For those children that reported zero recess times per week, a mean of 87.34% (± 3.57) of the daytime hours was recorded as light intensity activity, a mean of 11.99% (± 3.25) of the daytime hours was recorded as moderate intensity, and a mean of 0.67% (± 0.94) of daytime hours was recorded as vigorous intensity. The five minute moderate-vigorous activity bout frequency for those children who reported occasional recess times at school averaged 2.5 (± 0.55) daytime bouts according to the accelerometer data with a mean length per bout of 10.58 (± 1.29) minutes. The same activity bouts averaged 2.2 (± 0.57) bouts during daytime hours for those children who

had zero recess times during the school day with a mean length per bout of 10.35 (± 0.85) minutes. The mean steps per hour for the children who reported recess at least three times a week totaled 800 (± 88.59) steps while those with no reported recess time during school days averaged 686 (± 127.15) steps/hour. The mean vector magnitude or activity index of the children with occasional recess was 108946 (± 14783.37) counts while those without an occasional recess averaged 90708 (± 18835.52) counts per daytime hours.

Table 4.7 Physical Activity Dimensions with and without Recess (n=55)

Physical Activity Dimensions	**Recess 3-5 times/week during school day**		**Recess zero times/week during school day**	
	Mean (SD)	**Inclusive Range (Min-Max)**	**Mean (SD)**	**Inclusive Range (Min-Max)**
Activity Intensity (percentage of activity/day)				
Light	85.01 (3.72)	80.90-96.29	87.34 (3.57)	80.48-94.85
Moderate	14.24 (3.55)	3.22-18.43	11.99 (3.25)	4.86-17.85
Vigorous	0.75 (0.36)	0.19-1.73	0.67 (0.94)	0.13-5.54
Moderate-Vigorous Activity Bouts (number/daytime hours)	2.5 (0.55)	0.5-3.0	2.2 (0.57)	0.7-3.2
Length of Activity Bouts (minutes)	10.58 (1.29)	8.08-13.81	10.35 (0.85)	8.61-12.10
Steps per hour (number)	800 (88.59)	589-945	686 (127.15)	465-926
Vector Magnitude (counts)	108946 (14783.37)	79057-126979	90708 (18835.52)	56453-132622

Table 4.8 presents the physical activity dimensions by amounts of screen time per day. Those children who reported more than five hours per day of screen time recorded means of 87.19% (± 3.89) of their daytime activity as light intensity, 12.22% (± 3.70) of their daytime activity as moderate intensity, and 0.59% (±0.37) of their activity as vigorous intensity. Those children who reported two to five hours of screen time per day recorded means of 86.64% (± 3.87) of their daytime activity as light intensity activity, 12.41% (± 3.29) of their activity as moderate intensity, and 0.95% (± 1.47) of their activity as vigorous. Those children who

admitted to less than two hours of screen time per day recorded means of 84.61% (± 3.09) of their time as light intensity activity, 14.68% (± 2.96) of their time as moderate intensity activity and 0.72% (±0.34) of their activity as vigorous intensity activity. The number of moderate-vigorous activity bouts per day averaged 2.2 (± 0.69) for those children with over 5 hours of screen time, 2.3 (±0.43) for those children with 2-5 hours of screen time, and 2.5 (± 0.40) for those children with less than 2 hours of screen time. The mean length of the moderate-vigorous activity bouts for those children with over 5 hours of daily screen time was 10.35 (± 0.98) minutes. The mean activity bout time for those children with 2-5 hours of screen time was 10.20 (± 1.00) minutes while the bout time for those children with less than 2 hours of daily screen time was 10.82 (± 1.18) minutes. Steps per hour averaged 721 (± 115.87) for children with more than 5 hours of daily screen time, 671 (± 144.65) for children with 2-5 hours of screen time, and 807 (± 93.82) for children with less than 2 hours of screen time per day. Activity index or vector magnitude counts during daytime hours averaged 95962 (± 18283.61) counts for those children with over 5 hours of screen time per day, 89999 (± 22068.33) counts for children with 2-5 hours of screen time per day, and 109432 (± 14725.56) counts for children with less than 2 hours of screen time per day.

Table 4.8 Physical Activity Dimensions per Hours of Screen Time

Physical Activity Dimensions	>5 hours of screen time Mean (SD)	Inclusive Range (Min-Max)	2-5 hours of screen time Mean (SD)	Inclusive Range (Min-Max)	<2 hours of screen time Mean (SD)	Inclusive Range (Min-Max)
Intensity(%/day)						
Light	87.19 (3.89)	80.80-96.29	86.64 (3.87)	80.48–91.20	84.61 (3.09)	81.07-91.64
Moderate	12.22 (3.70)	3.22-17.81	12.41 (3.29)	8.56-18.43	14.68 (2.96)	7.94-18.17
Vigorous	0.59 (0.37)	0.18-1.73	0.95 (1.47)	0.13-5.54	0.72 (0.34)	0.19-1.37
M-V* bouts/day	2.2 (0.69)	0.5 – 2.9	2.3 (0.43)	1.7 – 3.2	2.5 (0.40)	1.4 - 3.0
Length/bout (in minutes)	10.35 (0.98)	8.08 – 12.49	10.20 (1.00)	8.80 – 12.10	10.82 (1.18)	9.28 - 13.18
Step/hour (number)	721 (115.87)	465-865	671 (144.65)	490 - 926	807 (93.82)	665 – 945
Vector Mag**	95962 (18283.61)	56453-132622	89999 (22068.33)	62403-124991	109432 (14725.56)	86661–126979

*Moderate-Vigorous activity bouts
** Vector Magnitude - daily accelerometer triaxial counts in 2 second epochs

Sleep Habits

Table 4.9 displays a noteworthy portion of the demographics and speaks to the consistency of a permanent place to sleep. Forty-two (76%) children stated that they slept in the same place, in their own bed, every night while thirteen (24%) children reported that they did not sleep in the same bed or their own bed every night. The options described for slumber accommodations for this latter portion of the sample included sofa, floor, rotating beds with siblings, or sharing a bed with a parent or relative.

Table 4.9 Sleep Accommodations (n=55)

Sleep Accommodations	Number (%)
Sleep in own bed every night	42 (76)
Sleep in different place most nights	13 (24)

Table 4.10 reports the sleep characteristics of this sample. Total sleep time, total number of wake episodes during the night, and average length of wake episodes were reported

objectively from accelerometer data. The mean sleep time per night for this sample was 483 (± 51.48) minutes with an inclusive range of 386.50 – 596.00 minutes per night. The mean number of wake episodes per night was 20.1 (± 6.9) with an inclusive range of 3.1 - 32.4. The mean length of each wake episode per night was 4.17 (± 1.65) minutes with an inclusive range of 1.9 to 10.69 minutes.

Table 4.10 Sleep Characteristics (n=55)

Characteristics	Mean (SD)	Inclusive Range (Min – Max)
Total Sleep Time (minutes)	483.00 (51.48)	386.50 – 596.00
Wake Episodes (number)	20.1 (6.9)	3.1 - 32.4
Average Length of Wake Episodes (minutes)	4.17 (1.65)	1.93 – 10.69

Table 4.11 compares the sleep characteristics in the children who had a consistent sleep place with the sleep characteristics in the children who slept in varied sleep locations. Those children who slept in a consistent place averaged 489.77 (± 60.94) minutes of sleep time per night while those that varied the locations of their slumber averaged 480.90 (± 48.84) minutes of sleep per night. The mean number of wake episodes was 21.4 (± 7.5) times per night for those who maintained a consistent sleep location and 19.7 (± 6.8) for those whose sleep location varied. The mean length of wake episodes for those children in the same sleep accommodations every night was 4.02 (± 1.48) minutes while those who slept in varying places per night averaged 4.21 (± 1.72) minutes per wake episode.

Table 4.11 Sleep Characteristics according to Sleep Accommodations (n=55)

Sleep Characteristics	Consistent Sleep Environment		Varied Sleep Environment	
	Mean (SD)	Inclusive Range (Min-Max)	Mean (SD)	Inclusive Range (Min-Max)
Total Sleep Time (minutes)	489.77 (60.94)	389.14-596.00	480.90(48.84)	386.50-585.00
Wake Episodes (number)	21.4 (7.5)	11.0–32.4	19.7(6.8)	3.1-32.0
Length of Wake Episodes (minutes)	4.02 (1.48)	2.21-7.14	4.21(1.72)	5.10–10.69

Weight Status

Anthropometric measures in this sample were consistently and discretely collected. Height was measured to the nearest inch on a stadiometer without shoes. Weight was taken three consecutive times on a calibrated digital scale and averaged. BMI was calculated from a pediatric age-specific calculation. (Table 3.2) For eight-year-old girls, a BMI > 20 qualifies as an obesity status for weight and > 18 qualifies as overweight. For eight-year-old boys, a BMI ≥ 20 qualifies as an obesity status for weight and ≥ 18 qualifies as overweight. Table 4.12a displays the height, weight, and the gender specific BMI breakdown of this sample. The average height and weight of these children was 53 (±4) inches and 82 (± 32.6) pounds, respectively. Weight ranged from 43.2 to 205.7 pounds. The average BMI for the sample was 20.2 (± 5.7) (obese) with an inclusive range of 13.8 to 38.9. Table 4.12b further illustrates the gender specific breakdown of this sample. According to the CDC Growth Chart trending, 3 (5%) of the children were underweight, 22 (40%) were normal weight, 11 (20%) were overweight, and 19 (35%) were obese. The majority of the boys were normal weight (55%) and the majority of girls (60%) of the girls were overweight/obese weight status. The girls' weight status varied from underweight to obese. There were no boys in the underweight category.

Table 4.12a Height, Weight, and BMI (Gender-specific)

Anthropometric Measures	**Mean (SD)**	**Inclusion Range (Minimum – Maximum)**
Height (inches)	53 (4)	47 - 61
Weight (pounds)	82.0 (32.6)	43.2 - 205.7
BMI*	20.2 (5.7)	13.8 – 38.9
Boys	19 (4.0)	14.4-27.4
Girls	20.8 (6.5)	113.8-38.9

*Age specific

Table 4.12b BMI Breakdown per Gender

BMI	Number (%)
Underweight	3 (5)
Boys	0
Girls	3 (9)
Normal weight	22 (40)
Boys	11 (55)
Girls	11 (31)
Overweight	11 (20)
Boys	3 (15)
Girls	8 (23)
Obese	19 (35)
Boys	6 (30)
Girls	13 (37)

Table 4.13 presents the BMI according to the amount of screen time per day, and according to the play frequency, both as reported by the children. Thirteen (68%) of the obese children (BMI > 20) claimed greater than 2 hours of screen time per day. Coincidentally, 13 (68%) children with a BMI >20 also stated that they had no regular daily play frequency. Eight (73%) of the overweight children (BMI>18) reported greater than 2 hours of screen time per day and six (55%) reported no daily play frequency. Sixteen (73%) of the normal weight children (BMI 14-18) stated that they enjoyed more than 2 hours of screen time per day and 13 (59%) did not play daily. All three (100%) of the underweight children watched more than 2 hours of screen time per day and did not enjoy regular, daily play time.

Table 4.13 BMI and Screen Time and Play Frequency (n=55)

BMI	Total Number	Screen Time		Play Frequency	
		>2 hours/day	<2 hours/day	Everyday	Not everyday
Obese	19				
Number (%)		13 (68)	6 (32)	6 (32)	13 (68)
Overweight	11				
Number (%)		8 (73)	3 (27)	5 (45)	6 (55)
Normal weight	22				
Number (%)		16 (73)	6 (27)	9 (41)	13 (59)
Underweight	3				
Number (%)		3 (100)	0	0	3 (100)

Study Feedback

Table 4.14 gives a summary of the qualitative feedback from the children on the experience of wearing the accelerometer for the better part of a week. Thirteen (13%) children described some sort of mild discomfort from wearing the monitor. All the distress was reported as a result of irritation from the wristband of the monitor. No physical rash or discoloration was seen on any of the children from the band. This reported sensation did not preclude wearing the monitor for the duration of the study for any of these children. One (2%) child stated acting differently while wearing the monitor in order to impress the researcher with physical aptitudes. All 55 (100%) children reported they could wear the monitor for a longer period of time than required by the study. All 55 (100%) children boasted that the monitor was noticed and commented on by others; this scientific trial gave them distinction.

Table 4.14 Study Feedback (n=55)

Subjective Reactions	**Number (%)**
Difficulty wearing monitor	13 (24)
Acted differently wearing the monitor	1 (2)
Could have worn the monitor longer	55 (100)
Monitor noticed / commented on by others	55 (100)

Academic Achievement

Three charter schools and three different methods for grading students' progress and achievements were realized. All of the teachers had criteria unique to their purpose of student work evaluation, motivation for continued improvement, and communication to parents and school authorities. Letter grades were given by only one of the school buildings. Lengthy written summaries were submitted by another one of the schools to include recommendations for advancement if appropriate. The final school campus emphasized oral presentations and oral conferences, with minimal written feedback, to convey progress and/or areas that needed improvement. Pass/Fail was the only common grading denominator among the three schools. Table 4.15 displays the pass/fail statistics. Forty-seven students, or 86% of the sample, passed the math requirements for their grade/school and 47 students, or 86% of the sample, passed the reading requirements for their grade/school. Interestingly, these 47 students were not the same students in each category. In other words, some of the third graders passed reading and did not pass mathematics and vice-versa

Table 4.15 Teacher Evaluations and Grades (n=55)

Subject	**Number (%)**
Mathematics	
Students passing	47 (86)
Language, Arts, Reading	
Students passing	47 (86)

The Michigan Educational Assessment Program (MEAP) is a set of evaluations administered by the State of Michigan for the purpose of reviewing, appraising, and comparing a student's mastery of grade-specific knowledge and essential skills, as defined by a subcommittee of the state's Board of Education. It is an assessment of grade-specific outcomes expected of all students in the State of Michigan. This standardized test is prepared for and instructed to in the schools' curriculum. The actual testing is administered in a strictly supervised manner and procedure, with strict guidelines. The reputation of the school and consequently many funding sources motivate the teachers and schools to assure that the children perform well on these examinations. Testing begins in the third grader. Third graders are tested in mathematics and reading only. All questions are multiple choices. The third grade students are scored according to four levels of proficiency. Each of these levels is subcategorized into three groupings: low, medium, and high.

Table 4.16 presents a detailed breakdown of the mathematics and reading proficiency levels. The mathematics scores cluster around Level 1 low (16 students), Level 2 high (11 students), and Level 2 medium (13 students). For reading scores, two students scored in Level 4 low and six students scored in Level 3 subcategories. Fourteen students achieved Level 2 medium, thirteen students attained Level 2 high scores while eight students realized Level 1 low scores in reading.

Schools boast of the percentage of students attaining an "at or above proficiency" level per grade-specific subject category as verification of competency and mastery grade-specific knowledge. "At or above proficiency scores" are reported as a combination of levels 1 and 2. Table 4.17 presents an itemized account of the mathematics and reading scores of the three Detroit charter schools as compared to the State of Michigan aggregate MEAP scores for all third grade students in the fall of 2010. Cumulatively the charter schools were comparable to the State of Michigan scores. Fifty-two (94%) children of the charter school third graders scored at or above the proficiency level in mathematics as compared to 95% of statewide third graders. Forty-seven (86%) children of the charter school third graders scored at or above the level in reading as compared to 87% of statewide third graders.

Table 4.16 MEAP Standardized Academic Scores per Proficiency Levels (n=55)

MEAP[a]	**LEVEL 4 Not Proficient**			**LEVEL 3 Partially Proficient**			**LEVEL 2 Proficient**			**LEVEL 1 Advanced**		
Mathematics	L[b]	M[c]	H[d]	L	M	H	L	M	H	L	M	H
Number/category	0	0	0	0	1	2	7	13	11	16	4	1
Reading	L	M	H	L	M	H	L	M	H	L	M	H
Number/category	0	0	2	1	1	4	7	14	13	8	5	0

[a] Michigan Educational Assessment Program
[b] Low
[c] Medium
[d] High

Table 4.17 Charter School MEAP Scores compared to State MEAP Scores per Proficiency Levels (n=55)

MEAP	**LEVEL 4** **Not Proficient**	**LEVEL 3** **Partially Proficient**	**LEVEL 2** **Proficient**	**LEVEL 1** **Advanced**	**Percent Proficient**
	Number (%)	**Number (%)**	**Number (%)**	**Number (%)**	
Mathematics					
Charter schools	0	3 (6)	31 (56)	21 (38)	94
State totals	0	(5)	(43)	(52)	95
Reading Scores					
Charter schools	2 (3)	6 (11)	34 (62)	13 (24)	86
State totals	(2)	(11)	(45)	(42)	87

Tables 4.18 and 4.19 illustrate a more detailed portrayal of selected individual characteristics and behaviors of the children according to the breakout of their MEAP placement scores. The subcategories per proficiency levels are itemized for MEAP reading and mathematics scores for those children who ate at least one meal/day with the family, enjoyed at least one outdoor playtime/day, watched less than 2 hours of screen time/day, and slept in a consistent location/night. Levels 1 and 2 are considered proficient and passing. Levels 3 and 4 are considered not proficient and unacceptable for passing.

Table 4.18 displays the MEAP reading scores. Thirteen (24%) children of the total population placed in Level 1; 34 (62%) children placed in Level 2; six (11%) children placed in Level 3; and two (3%) children placed in Level 4. The table illustrates that 11 (85%) children of those that achieved Level 1 proficiency (Advanced) had at least one meal/day with family, 5 (38%) children played outside at least once/day, 7 (54%) children watched less than 2 hours of screen time/day, and 10 (77%) children slept in a consistent location each night. Eighteen children, or 53% of those that achieved Level 2 proficiency (Proficient), had at least one meal per day with family, 11 (32%) children played outside at least once per day, 8 (23%) children watched less than 2 hours of screen time/day, and 26 (76%) children slept in a consistent location each night. Three, or 50% of those that scored at the Level 3 proficiency (Partially proficient) had at least one meal per day with family, two (33%) children played outside at least once per day, six (100%) of the children enjoyed more than 2 hours of screen time per day, and 4 (67%) children slept in a consistent location each night. Of the two children that scored at the Level 4 proficiency (Not proficient), two (100%) stated that they had at least one meal per day with family, one (50%) played outside at least once per day, two watched more than 2 hours of screen time per day, and two slept in a consistent location each night.

Table 4.18 MEAP Reading Scores per Individual Behaviors (n=55)

MEAP Reading Scores	**Level 4 Not Proficient**	**Level 3 Partially Proficient**	**Level 2 Proficient**	**Level 1 Advanced**
Proficiency Level (Number and Percent)	2 (3)	6 (11)	34 (62)	13 (24)
Meals with family (Number and Percent)	2 (100)	3 (50)	18 (53)	11 (85)
Play every day (Number and Percent)	1 (50)	2(33)	11 (32)	5 (38)
Screen time <2h/d (Number and Percent)	0	0	8 (23)	7 (54)
Consistent sleep local (Number and Percent)	2 (100)	4 (67)	26 (76)	10 (77)

Table 4.19 presents the MEAP mathematics scores. Twenty-one children, or 38% of the total sample, placed in Level 1; 31 (56%) children placed in Level 2; 3 (6%) children placed in Level 3; and none of the children scored in Level 4. The table reveals that 14 children, or 67% of those that achieved Level 1 proficiency (Advanced), had at least one meal per day with family, 8 (38%) children played outside at least once per day, 10 (48%) children watched less than 2 hours of screen time/day, and 18 (86%) children slept in a consistent location each night. Seventeen children, or 55% of those that achieved Level 2 proficiency (Proficient), had at least one meal per day with family, 11 (35%) children played outside at least once per day, 4 (13%) children watched less than 2 hours of screen time per day, and 15 (48%) children slept in a consistent location every night. Three children from the sample scored at the Level 3 proficiency

(Partially proficient) in mathematics. None of these three children admitted to eating any daily meals with their family, or playing outside on a daily basis. The three children at Level 3 watched more than 2 hours per day of screen and consistently slept in the same location each night.

Table 4.19 MEAP Mathematics Scores per Individual Behaviors (n=55)

MEAP Mathematics Scores	**Level 4 Not Proficient**	**Level 3 Partially Proficient**	**Level 2 Proficient**	**Level 1 Advanced**
	Number (%)	**Number (%)**	**Number (%)**	**Number (%)**
Meals with family	0	0	17 (55)	14 (67)
Play every day	0	0	11 (35)	8 (37)
Screen time <2h/d	0	0	4 (13)	10 (48)
Consistent sleep local	0	3 (100)	15 (48)	18 (86)

Research Question 1. Objective pattern of physical activity and sleep

A summary of the descriptive statistical analysis per SPSS suggests relatively small standard deviations portraying a fairly homogenous sample population. Research question one was: W*hat is the objective pattern of physical activity and sleep over the week in this cohort of eight year olds living in a low socioeconomic urban area*? Table 4.20 displays the objective sleep and physical activity data and patterns. The mean percent of light physical activity was 86% (± 3.78), moderate physical intensity activity was 13% (± 3.53), and the mean percent of vigorous physical activity was .7% (± .75). This sample averaged 2.33 (± .58) bouts of moderate-vigorous activity per day, lasting on average 10.45 minutes (± 1.05). An average of 733 (± 125) steps was taken per hour with the mean vector magnitude counts registering at 98335 (±19368) per hour. The average steps per day were 10999 (± 1879.51); the mean steps taken per day by the girls were 11007 (±1697.07) and the mean steps taken per day by the boys were 10984.67 (±2210). The children slept a mean of 483 (± 51) minutes (slightly over 8 hours) per night. Each child woke up on average 20 (± 6.93) times a night. The average length of wake episodes was 4 (± 1.65) minutes, according to the accelerometer counts. Total average arousal time per child was 79 minutes per night.

Table 4.20 Activity and Sleep Patterns (n=55)

Activity/Sleep Data	Mean (SD)	Inclusive Range Min-Max
Physical Activity		
Light intensity (%)	86.36 (3.78)	80.48-96.29
Moderate intensity (%)	12.93 (3.53)	3.22-18.43
Vigorous intensity (%)	0.70 (0.75)	0.13-5.54
Activity bouts (number)	2.33 (0.58)	0.50-3.20
Length per bout (minutes)	10.45 (1.05)	8.08-13.81
Steps per hour	733.28 (125.30)	464.55-944.84
Steps per day	10999.19 (1879.51)	6968.25-14172.60
Girls	11007.43 (1697.07)	6968.25-14088.15
Boys	10984.67 (2210.40)	7049.40-14172.60
Vector Magnitude (counts)	98334.69 (19368.48)	56452.99-132622.40
Sleep		
Sleep in minutes	483.00 (51.48)	386.50-596.00
Wake episodes/night (number)	20.11(6.93)	3.10-32.40
Length of wake episodes (minutes)	4.16 (1.65)	1.93-10.69
Average arousal time/night (minutes)	79.13 (29.74)	7.50-163.51

Research Question 2. Physical activity dimensions and objective sleep characteristics

Research question two was: *What is the relationship between patterns of free-living (unstructured) physical activity dimensions and objective sleep characteristics in a cohort of eight-year-old children?* The correlations between objectively measured free-living physical activity dimensions and sleep characteristics are displayed in Table 4.21. The activity bouts were filtered on the accelerometer to capture daytime moderate to vigorous intensity bouts. There was an inverse correlation between number of bouts with light intensity activity (r = -0.87; p<0.0001) and the length of bouts with light intensity activity (r= -0.39; p=0.004). There was a positive correlation between the number of bouts with moderate intensity activity (r=0.86; p< 0.0001) and the length of bouts with moderate intensity activity (r=0.43; p= 0.001). There was also a positive correlation between vigorous intensity activity and number of bouts (r=0.34; p=0.011). An inverse correlation was realized between the number of moderate-vigorous activity bouts and the hours of sleep per night (r= -0.28; p=0.04). Additionally, the number of moderate-vigorous activity bouts was positively and significantly correlated with the number of wake episodes during the night time hours (r= 0.32; p=0.017). Percentage of light intensity activity per day was negatively correlated with number of night wake episodes (r= -0.29; p=0.033). The percentage of moderate intensity activity per day was positively correlated with the number of night wake episodes (r=0.29; p=0.029). Number of steps per hour was inversely correlated with the length of wake episodes at night (r= -0.31; p=0.023). The vector magnitude was also inversely correlated with the length of wake episodes at night (r=-0.31; p=0.023).

It is noteworthy to mention correlations in this table relate different aspects and relationships amongst the dimensions of physical activity. There is a positive correlation between the number of steps taken per hour and the vector magnitude counts per hour (r= 0.94; p< 0.0001). In addition, the vector magnitude counts and the daily step counts per day are inversely correlated with light activity (r= -0.59; p<0.0001) and (r= -0.61; p<0.0001), respectively. The vector magnitude counts and the daily step counts per day are also correlated with moderate activity (r=0.63; p<0.0001) and (r=0.66; p<0.0001), respectively. The number of activity bouts is positively correlated with steps per hour (r= 0.45; p=0.001) and vector magnitude counts per hour (r=0.41; p=0.002). The length per activity bout is also correlated with steps per hour (r=0.42; p=0.001) and vector magnitude counts per hour (r=0.34; p=0.010).

Table 4.21 Correlations between Physical Activity and Sleep (n=55)

	LITE	MOD	VIG	BOT	LBOT	SLEP	WAK	LWA	AROS	STEP	VECT
LITE [a]	1										
MOD [b]	-.98**	1									
VIG [c]	-.42**	.24	1								
BOT [d]	-.87**	.86**	.34*	1							
LBOT [e]	-.39**	.43**	-.09	.15	1						
SLEP [f]	.14	-.17	.09	-.28*	-.19	1					
WAK [g]	-.29*	.29*	.07	.32*	-.01	-.15	1				
LWA [h]	.20	-.17	-.23	-.16	.11	-.25	-.41**	1			
AROS [i]	-.14	.18	-.14	.17	.09	-.41**	.63**	.33*	1		
STEP [j]	-.61**	.66**	-.03	.45**	.42**	-.03	.13	-.31*	-.024	1	
VECT [k]	-.59**	.63**	.01	.41**	.34*	.01	.12	-.31*	-.007	.94**	1

[a] Light intensity percentage/daytime hours
[b] Moderate intensity percentage/daytime hours
[c] Vigorous intensity/percentage/daytime hours
[d] Activity bouts during daytime hours
[e] Length of activity bout
[f] Sleep
[g] Number of Wake episodes during the night
[h] Length of Wake episodes during the night
[i] Total nighttime arousal time (number of wake episodes x length of wake episodes)
[j] Steps per hour
[k] Vector magnitude
** Correlation is significant at 0.01 level (2-tailed)
* Correlation is significant at 0.05 level (2-tailed)

Research Question 3. Physical activity dimensions and the weight status

Research question three was: *What is the relationship between patterns of free-living physical activity dimensions and the weight status as measured by body mass index (BMI) in a cohort of eight year old children?* Table 4.22 displays the correlations between physical activity dimensions and weight status as measured by body mass index. No correlation is seen in any dimension of physical activity with weight status as measured by BMI. Additionally, no gender differences or correlations were seen in any of the physical activity dimensions.

Table 4.22 Correlation between Physical Activities and Weight (n=55).

	LITE	**MOD**	**VIG**	**BOUT**	**LBOUT**	**STEPS**	**VECTR**	**BMI**
LITE [a]	1							
MOD [b]	-.98**	1						
VIG [c]	-.42**	.24	1					
BOUT [d]	-.87**	.86**	.34*	1				
LBOUT [e]	-.39**	.43**	-.09	.15	1			
STEPS [f]	-.61**	.66**	-.03	.45**	.42**	1		
VECTR [g]	-.59**	.63**	.01	.41**	.34*	.94**	1	
BMI	-.07	.05	.11	.21	.05	-.01	-.08	1

[a] Light intensity percentage/daytime hours
[b] Moderate intensity percentage/daytime hours
[c] Vigorous intensity/percentage/daytime hours
[d] Activity bouts during daytime hours
[e] Length of activity bout
[f] Steps/daytime hour
[g] Vector Magnitude
** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Research Question 4. Physical activity and the psychosocial indicators of academic achievement and academic behavior

Research question four was: *What is the relationship between patterns of free-living physical activity and the psychosocial indicators of academic achievement and academic behavior in a cohort of eight-year-old children?* The correlations between patterns of free-living physical activity and the psychosocial indicators of academic achievement behavior are displayed in Table 4.23. The MEAP (Michigan Educational Assessment Program) levels were numbered consecutively according to level and subcategory for the purpose of this analysis. The level 1 (high) score received a number of 1; level 1(medium) score received a number of 2; the level 1 (low) score received a number of 3; the level 2 (high) score received a number of 4; and so on. Percent of light intensity activity per day is positively and significantly correlated with days of absenteeism (r=0.35; p=0.008) as well as percent of days missed per child (r=0.31; p= 0.020). Percent of moderate intensity activity per day is inversely and significantly correlated with days of absenteeism (r= -0.35; p=0.009) as well as percent of days missed per child (r= -0.31; p=0.022). There is no relationship seen between vigorous activity and attendance at school in this sample. Number of five minute moderate-vigorous activity bouts per day is inversely and significantly correlated with the number of missed school days (r= -0.37: p=0.006) as well as the percent of days missed per child (r= -0.32; p=0.019). Interestingly, the number of activity bouts per day is inversely significantly correlated with the MEAP reading levels and the standardized MEAP reading scores (r= -0.27; p=0.048) and (r= -0.31; p=0.023), respectively. The mean number of steps per hour is inversely and significantly correlated with the number of days missed per child as well as the percent of missed days per child (r= -0.31; p=0.021) and (r= -0.32; p=0.018), respectively. The vector magnitude counters are also inversely and significantly correlated with the number of days missed per child as well as the percent of missed days per child (r= -0.33; p=0.02) and (r= -0.34; p=0.011), respectively. Percent of missed school days is positively and significantly correlated with the number of absent days from school (r=0.99; p<0.0001).

Table 4.23 Correlation between Physical Activity and Psychosocial Indicators (n=55)

	ATTEND	PMISSED	LMMEAP	SMMEAP	LRMEAP	SRMEAP
Light intensity	.35**	.31*	.17	-.24	.24	-.24
Moderate intensity	-.35**	-.31*	-.18	.25	-.23	.24
Vigorous intensity	-.13	-.12	-.034	.02	-.15	.14
Number of bouts	-.37**	-.31*	-.23	.24	-.27*	.31*
Length of bouts	.02	.04	-.01	.11	-.11	.07
Steps per day	-.31*	-.32*	-.16	.21	-.03	.04
Vector Magnitude	-.33*	-.34*	-.12	.17	.03	-.02
Attendance[a]	1	.99**	.14	-.21	-.01	-.02
% days missed[b]	.99**	1	.12	-.19	-.06	.02

[a] Days missed
[b] Percentage of days missed/child

Research Question 5. Physical activity and sleep variables in those who passed and failed school reading and mathematics

Research question five was: *Are there differences in physical activity and sleep variables between those who passed and those who failed school reading and mathematics*? Table 4.24 illustrates differences between two groups in this sample, those students with failing reading grades and those students with passing reading grades as rendered by the third grade teachers of each respective charter school. A *t-test* analysis was conducted to analyze the differences between these two groups in the areas of physical activity dimensions (levels of activity intensities, sleep characteristics, BMI, vector magnitude, and steps/hour). Levine's test for equality of variance was performed and the appropriate *t value* utilized. The analysis shows several significant differences between the group means. Students with failing reading grades had significantly more days absent from school (mean = 22.6 days missed) (± 11.13) than the students with passing reading grades (mean = 11.3 days missed) (± 8.29), with equal assumed variances (t= 3.39, p=0.001). Those students with failing reading grades had significantly more time per day spent in light/sedentary activity (mean = 89.6% light intensity activity) (±3.60) than those students with passing reading grades (mean = 85.8% light intensity activity) (± 3.55), with equal assumed variances (t=2.81, p=0.007). Students with failing reading grades had significantly less time per day spent in moderate intensity activity (mean = 9.9% moderate intensity activity) (± 3.53) than those students with passing reading grades (mean = 13.4% moderated intensity activity) (± 3.31), with equal assumed variances (t= -2.73, p=0.008). Those students with failing reading grades had significantly less steps/hour counted per the accelerometer (mean = 624) (± 120.21) than those students with passing reading grades (mean = 752) (± 117.52), with equal assumed variances (t= -2.83, p= 0.007). Students with failing reading grades had a significantly lower vector magnitude index (mean=80486) (±14350.92) than those students with passing reading grades (mean= 101372) (±14350.92), with equal assumed variances (t= -3.02, p=0.004). There was no significant difference between the two group means according to this analysis with any of the other listed measures, including hours spent in sleep per night, vigorous intensity time per day, BMI, number and length of wake episodes at night, and number and length of activity bouts per day.

Table 4.24 Differences between Pass/Fail Reading Students by Physical Activity Dimensions (n=55)

	Mean (SD)	***t-value***	***p-value***
School days missed			
Failing students	22.62 (11.13)	3.39	0.001
Passing students	11.29 (8.29)		
Light Physical INTENSITY			
Failing students	89.64 (3.60)	2.81	0.007
Passing students	85.81 (3.55)		
Moderate Physical INTENSITY			
Failing students	9.95 (3.53)	-2.73	0.008
Passing students	13.44 (3.31)		
SLEEP time/night			
Failing students	473.37 (70.54)	-0.57	0.572
Passing students	484.64 (48.33)		
STEPS per hour			
Failing students	624.21 (120.21)	-2.83	0.007
Passing students	751.84 (117.52)		
VECTOR Magnitude			
Failing students	80486.15 (14350.92)	-3.02	0.004
Passing students	101372.74 (18552.78)		
Vigorous Physical INTENSITY			
Failing students	0.41 (0.17)	-1.20	0.234
Passing students	0.75 (0.79)		
BMI			
Failing students	17.39 (2.94)	-1.49	0.140
Passing students	20.62 (5.95)		
Number WAKE episodes			
Failing students	17.26 (7.27)	-1.26	0.211
Passing students	20.59 (6.83)		
Length of WAKE episodes			
Failing students	4.89 (1.69)	1.36	0.179
Passing students	4.04 (1.63)		
Length of BOUTs			
Failing students	10.35 (0.49)	-0.47	0.639
Passing students	10.46 (1.12)		
Number of BOUTs			
Failing students	1.85 (0.79)	-1.92	0.091
Passing students	2.41 (0.51)		

Table 4.25 explicates the differences in the above variables in two different groups in this sample. Those students with failing mathematics grades and those students with passing mathematics grades as rendered by the third grade teachers showed no significant difference in group means according to *t-test* analysis regarding the physical activity dimensions, BMI, and attendance. The group did however show significant differences in the mean length of wake episodes during the night. The students that were failing mathematics had a mean wake episode of 5.52 minutes (± 1.68) while the passing mathematics students had a mean wake episode of 3.93 minutes (± 1.55) (t = 2.64, p = 0.011). The group means for the fail/pass mathematics students did not show the same differences as the fail/pass reading student groups.

Table 4.25 Differences between Pass/Fail Mathematics Students by Physical Activity Dimensions n=55)

	Mean (SD)	*t-value*	*p-value*
School days missed			
Failing students	20.62 (13.18)	1.87	0.099
Passing students	11.63 (8.26)		
Light Physical INTENSITY			
Failing students	87.92 (4.84)	1.26	0.212
Passing students	86.09 (3.57)		
Moderate Physical INTENSITY			
Failing students	11.66 (4.75)	-1.11	0.273
Passing students	13.15 (3.29)		
SLEEP time/night			
Failing students	486.02 (60.16)	0.18	0.860
Passing students	482.49 (50.58)		
STEPS per hour			
Failing students	700.87 (151.29)	-0.79	0.434
Passing students	738.79 (121.38)		
VECTOR Magnitude			
Failing students	90459.44 (18471.15)	-1.25	0.217
Passing students	99675.16 (19386.55)		
Vigorous Physical INTENSITY			
Failing students	0.42 (0.17)	-1.14	0.259
Passing students	0.75 (0.79)		
BMI			
Failing students	18.87 (5.81)	-0.68	0.500
Passing students	20.37 (5.73)		
Number WAKE episodes			
Failing students	16.52 (5.10)	-1.61	0.114
Passing students	20.72 (7.05)		
Length of WAKE episodes			
Failing students	5.52 (1.68)	2.64	0.011
Passing students	3.93 (1.55)		
Length of BOUTs			
Failing students	11.03 (0.76)	1.72	0.091
Passing students	10.35 (1.07)		
Number of BOUTs			
Failing students	1.95 (0.84)	-1.45	0.184
Passing students	2.39 (0.51)		

Table 4.26 compares the group means between the students that received failing and passing math and reading grades from their teachers with the MEAP math and reading scores. The *t-test* analysis was run through SPSS. Levine's test for equality of variances was not significant, indicating that the variances were equal and the *t-test* was appropriate. The analysis indicated that the students who received a failing grade in mathematics and reading from their teachers, did significantly worse on the respective MEAP tests. Table 26 specifically reports that the mean group differences between the failing math students (305.75) (± 11.68) and the passing math students (325.81) (± 16.54) were significant (t= -3.28, p=0.002). Additionally, the table indicates that the mean group differences between the failing reading students (mean=307.00) (± 19.91) and the passing reading students (mean=324.11) (± 22.06) were significant (t= -2.05, p=0.045).

Table 4.26 MEAP Scores and Teacher Assigned Fail-Pass Grades

	Mean (SD)	***t-value***	***p-value***
MEAP Math scores			
Failing students	305.75 (11.68)	-3.28	0.002
Passing students	325.81 (16.54)		
MEAP Reading scores			
Failing students	307.00 (19.91)	-2.05	0.045
Passing students	324.11 (22.06)		

Research Question #6 To what extent does a linear composite of demographic variables (sleep characteristics, weight status, academic achievement, and academic behavior) have a relationship with a linear composite of physical activity in a cohort of eight-year-old children?

To address Research Question 6, canonical correlation analysis was used. The first canonical correlation was 0.62. The probability level for the null hypothesis that all the canonical correlations are zero in the population was 0.2381. Thus, the correlation between the two linear composites was statistically nonsignificant. The squared canonical correlation for the first canonical correlation was 0.38. That is, 38% of the variance is shared by the two linear composites. The most important variables in this standardized linear composite of physical activity were light intensity activity and moderate intensity activity. The most important demographic characteristic variables were hours of sleep, number of days absent from school, and number of wake episodes per night, followed by BMI and average length (minutes) of wake episodes at night.

Additional Findings

In order to determine differences in physical and behavioral characteristics per body weight classification, a one-way ANOVA was performed as seen in Table 4.27. The independent variable (factor) was identified as body weight category, with three levels; obese (19 children at a BMI > 20), overweight (11 children at a BMI > 18), and normal weight (25 children with a BMI ≤ 18). The dependent variables were hours of sleep per night, steps taken per daytime hours, number of moderate-vigorous activity bouts per day, and percent each day of light, moderate, and vigorous intensity activity. One of the dependent variables indicated a significant difference with the weight level categories of children. With critical values for *F* at 3.18 (5%) and 5.06 (1%) for this sample, at a probability level of 0.05, we reject the null hypothesis and conclude that there is significant difference between the obese, overweight, and normal weight child related to the minutes of sleep per night (p =0.02).

Table 4.27 Group Differences per Weight Classifications

	OBESE MEAN (SD)	**OVERWEIGHT** MEAN (SD)	**NORMAL** MEAN (SD)	**F**	***p-value***
Sleep	470.67 (56.48)	457.62 (38.72)	503.17 (45.89)	4.27	0.019
Steps / hour	749.47 (115.13)	728.91 (91.22)	720.68 (143.38)	0.29	0.749
Bouts	2.42 (0.62)	2.53 (0.34)	2.12 (0.63)	2.40	0.101
Light intensity	86.18 (3.87)	85.61 (2.81)	87.18 (4.16)	0.76	0.473
Moderate intensity	12.93 (3.45)	13.92 (2.69)	12.16 (3.94)	0.96	0.389
Vigorous intensity	0.89 (1.20)	0.47 (0.24)	0.66 (0.32)	1.19	0.312

The BMI-for-age between boys and girls in this cohort was not significantly different per t-test analysis as seen in Table 4.27a (*t= -1.09, p=0.28*).

Table 4.27a Gender Differences per BMI

	Gender	N	Mean
BMI	BOYS	20	19.04 (4.01)
	GIRLS	35	20.78 (6.46)

The obese children slept an average of thirty-two minutes less each night and the overweight children slept an average of forty-six minutes less each night, as seen in Table 4.28.

Table 4.28 Hours of Sleep by Weight Category

Weight Class	Number / Category	Mean Minutes of Sleep (SD)	Difference from Normal Group
Obese	19	470.67 (56.48)	-32.50 minutes
Overweight	11	457.62 (38.72)	-45.55 minutes
Normal	25	503.17 (45.80)	0 minutes

To further investigate the differences between weight groupings, Table 4.29 displays differences in sleep characteristics and physical activity dimension means between obese/overweight children (30) and the normal/underweight (25) children according to BMI classification. There is one area of significance seen in this analysis between the higher weight category (> 18 BMI) and the lower weight category (≤ 18 BMI). With equal variance assumed according to Levine's test, the number of minutes slept is significantly different between the two groups (t = 2.88, p=0.006). The mean number of minutes slept by the obese/overweight children is 465.8 (± 50.38) minutes or 7.7 hours per night. The mean number of minutes slept by the normal/underweight group of children is 503.5 (± 45.73) minutes or 8.4 hours per night. The heavier children slept, on average, 37 minutes less per night than the normal or underweight children.

Table 4.29 Sleep and Physical Activity according to Weight Category

	Weight Class	Group Mean (SD)	*t-value*	*p-value (2-tailed)*
Number Activity Bouts[a]	Normal weight	2.17 (0.62)	-1.86	0.068
	Obese/Overweight	2.46 (0.53)		
Sleep per night[b]	Normal weight	503.54 (45.73)	2.88	0.006
	Obese/Overweight	465.88 (50.38)		
Steps per day[c]	Normal weight	722.83 (146.97)	-0.54	0.589
	Obese/Overweight	741.98 (105.76)		
Moderate intensity activity[d]	Normal weight	12.50 (3.93)	-0.83	0.412
	Obese/Overweight	13.29 (3.18)		
Vigorous intensity activity[e]	Normal weight	0.66 (0.31)	-0.36	0.716
	Obese/Overweight	0.74 (0.98)		
Standardized Math[f]	Normal weight	322.20 (21.69)	-0.27	0.791
	Obese/Overweight	323.47 (13.10)		
Standardized Reading[g]	Normal weight	322.32 (19.19)	0.21	0.835
	Obese/Overweight	321.03 (25.12)		

[a] Activity Bouts per day
[b] Sleep minutes per night
[c] Steps per daytime hours
[d] Moderate intensity activity (daily percent of)
[e] Vigorous intensity activity (daily percent of)
[f] Scores of Math MEAP
[g] Scores of Reading MEAP

Table 4.30 gives correlational meaning to several sleep and physical activity characteristics specific to the obese children in this sample. The obese eight-year-olds showed an inverse significant correlation between light intensity activity and moderate intensity activity (*r*= -0.95, *p*<0.0001), vigorous intensity activity (*r*= -0.49, *p*=0.034), and number of activity bouts per day (*r*= -0.91, *p*<0.0001). A positive correlation was seen between the number of activity bouts and moderate activity intensity (r=0.89, p<0.0001). No significant correlations were seen involving sleep or number of steps per hour.

Table 4.30 Obesity Correlates (n=19)

	Light intensity activity/day	Moderate intensity activity/day	Vigorous intensity activity/day	Number of activity bouts/day	Number of steps/hour	Minutes of sleep/night
Light intensity activity	1					
Moderate intensity activity	-0.95**	1				
Vigorous intensity activity	-0.49*	0.19	1			
Number activity bouts	-0.91**	0.89**	0.39	1		
Steps/hour	-0.25	0.40	-0.34	0.07	1	
Sleep/night	0.09	-0.18	0.22	-0.24	0.22	1

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed)

Table 4.31 presents correlations between physical activity and sleep variables in the overweight group of eight-year-olds. The overweight children showed no significant correlations with sleep or physical activity variables. There was an inverse relationship noted between light intensity activity and moderate intensity activity (*r*= - 0.99, *p*<0.0001), number of activity bouts per day (*r*= -0.71, p= 0.015, and number of steps per hour (*r*= -0.89, *p* <0.0001).

In addition, in this overweight sample, there was a positive correlation between number of bouts of activity per day and number of steps taken per daytime hour (*r*= 0.78, *p* =0.005).

Table 4.31 Overweight Correlates (n=11)

	Minutes of sleep/night	Light intensity activity/day	Moderate intensity activity/day	Vigorous intensity activity/day	Number of activity bouts/day	Number of steps/hour
Sleep/night	1					
Light intensity activity	0.31	1				
Moderate intensity activity	-0.27	-0.99**	1			
Vigorous intensity activity	-0.59	-0.52	0.45	1		
Number activity bouts	-0.15	-0.71*	0.69*	0.45	1	
Steps/hour	-0.41	-0.89**	0.89**	0.47	0.78**	1

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed)

Table 4.32 shows the correlations in the normal weight eight-year-olds between physical activity and sleep variables. Light intensity activity was inversely correlated with moderate intensity activity (r= -0.99, p<0.0001), vigorous intensity activity (r= -0.71, p<0.0001), number of activity bouts per day (r= -0.88, p<0.0001), and number of steps per hour (r= -0.67, p=0.001). Moderate intensity activity is positively correlated with vigorous activity (r=0.66, p=0.001), number of bouts per day (r=0.89, p<0.0001), and number of steps per hour (r= 0.67, p=0.001). Vigorous activity intensity positively and significantly correlated with number of bouts of activity per day (r= 0.56, p=0.006). The number of activity bouts per day significantly correlated with the number of steps per hour (r=0.57, p=0.006).

Table 4.32 Normal Weight Correlates (n=22)

	Light intensity activity/day	Moderate intensity activity/day	Vigorous intensity activity/day	Number of activity bouts/day	Number of steps/hour	Minutes of sleep/night
Light intensity activity	1					
Moderate intensity activity	-0.99	1				
Vigorous intensity activity	-0.71	0.66	1			
Number activity bouts	-0.88	0.88	0.56	1		
Steps/hour	-0.67	0.67	0.39	0.56	1	
Sleep/night	-0.04	0.05	-0.01	-0.07	-0.08	1

**. Correlation is significant at the 0.01 level (2-tailed).

There were only three children in the underweight category in this population. The only significant correlation seen in this weight category was the inverse relationship between the percentage of light activity intensity per day and the percentage of moderate activity intensity daily (r=-0.99, p=0.031).

Table 4.33 summarizes the different physical activity correlates as they compare across different weight classifications. The underweight child shows a significant correlation between light and moderate intensity activity only. There are many similarities between the correlations among the normal weight children and the overweight children. The normal weight, overweight, and obese children have inverse correlations between light intensity activity and the moderate intensity activity, vigorous intensity activity, and number of activity bouts per day. The normal weight and overweight child also show an inverse correlation between the number of steps per hour and light intensity activity. The normal weight, overweight, and obese children demonstrate significant positive correlations between the number of bouts per day and moderate activity intensity. The normal weight and overweight children illustrate a positive, significant correlation between the number of steps per hour and moderate intensity activity. Only the normal weight children show a significant positive correlation between vigorous intensity and moderate intensity and number of activity bouts per day. Lastly the normal weight children and the overweight children demonstrate a significant and positive correlation between the number of activity bouts per day and the number of steps per hour.

Table 4.33 Comparison of Weight Classifications related to Physical Activity (n=55)

		Underwt	**Normal**	**Overwt**	**Obese**
↑ Light activity	↓ Moderate intensity	X	X	X	X
	↓ Vigorous intensity		X	X	X
	↓ Number of bouts/day		X	X	X
	↓ Number of steps/hour		X	X	
↑ Moderate intensity	↑ Number of bouts/day		X	X	X
	↑ Number of steps/hour		X	X	
↑ Vigorous intensity	↑ Moderate intensity		X		
	↑ Number of bouts/day		X		
↑ Number of activity bouts/day	↑ Number of steps per hour		X	X	

CHAPTER FIVE

Discussion of Results

This study examined the correlations between physical activity dimensions and sleep characteristics in 8-year-old school children using a triaxial accelerometer. In addition, this research addressed the relationships among several psychosocial indicators (weight status, academic performance, academic behavior) and sleep and physical activity.

Initially, formulation was based on a critical effect size of .30, 80% power, and a significance level of 0.005 (adjusted for at least 10 outcome variables). Sample size was determined to be 125 subjects. However, the recruitment and enrollment process of this study proved to be more challenging than expected. Not all of the third grade teachers welcomed the research experience. The goal was to keep the teacher burden minimal, yet it was necessary to request teacher participation in obtaining the students' grades and evaluations, MEAP scores, and attendance records. Recruitment was facilitated and enhanced by the teachers that promoted and re-enforced the research study protocol. The involvement from the parents/caregivers in the home was inconsistent and infrequent. The vast majority of children, however, were anxious to participate and eager to comply with the instructions given. Yet, various socio-demographic forces frustrated and countered many of their endeavors. Quite frequently and much to the dismay of the children, the parent and/or caregiver simply failed to read, sign, and return the consent form. Multiple consent forms were often sent home with the children, often to no avail. Additionally, incorrect information was conveyed to the students by the parents/caregivers, secondary to either misreading or misunderstanding the content of the consent form. Several students received erroneous instructions on care and use of the monitor, causing elimination from the study.

The three charter school campuses had an estimated total of 180 third grade students. Slightly over 15% (30 students) were not eight-years-of age in the third grade, leaving an eligible recruitment pool of a probable 160 students. Seventy-five, 47% of eligible children, signed consent forms. Fifty-five children successfully wore the monitors for the required time. Consequently, sample size was revisited and reformulated. Based on a formulation of 80% power, a critical effect size of .50, and a significance level of 0.005 (adjusted for at least 10 outcome variables), a sample of 47 subjects was deemed sufficient to address the study research questions. The Gpower computer software (Version 3.0.10) was used to calculate the required sample size. (Faul, Erdfelder, Lang, & Buchner, 2007). Precedent has been set for this critical effect size in the majority of studies reviewed (Bonomi, Goris, Yin, & Westerterp, 2009; Butte, Puyau, Adolph, Vohra, & AZakeri, 2007; McMall, McGuigan, & Nottles, 2009; Puyau, Adolph, Vohra, & Butte, 2002; Puyau, Adolph, Vohra, Zakeri, & Butte, 2004; Sirard & Pate, 2001; Tudor-Locke, Ainsworth, Thompson, & Matthews, 2002).

Sample Demographics

According to the descriptive statistical analysis this sample of 55 eight-year-old children was demographically fairly homogenous. The children all attended the third grade at one of three urban charter schools. Enrollment in the study was conducted through the cooperation of these three geographically close charter schools. The study sample was predominantly African American and of low socioeconomic status according to the criterion for qualifying for the federal school lunch program. Per the 2009 U.S. Census Bureau, 38.2% of the families in this urban city have an income in the past twelve months below the poverty level. This is the largest number of U.S. people in poverty throughout the entire 51 years that poverty estimates have been published by the Census Bureau. According to data from the Pediatric Nutrition Surveillance

System, low-income children are statistically more likely to be obese regardless of geographic variability. Research has also shown that pre-adolescents from higher income backgrounds experienced significantly higher overall physical activity levels (Maher & Olds, 2011). These income-related differences were explained by the unique extra-curricular availabilities and types of moderate-vigorous activities accessible to a higher income population.

The study sample was evenly split in terms of single or dual parent homes as well as the educational level of the parents. Previous research has shown positive associations between maternal education, family income and physical activity levels among adolescents (Van Der Horst, Paw, Twisk, & Van Mechelen, 2007). According to the self-reporting of the children, a parent typically cared for them during after school hours. Nearly half of the parents had completed high school and about half had completed some portion of a post high school education. The uncertainty of the children related to the number of siblings spoke conspicuously to the lack of family continuity and permanence in this cohort of children.

No public transportation was available to these children. It was not safe to walk to school and thus the only alternative for transportation to school was driving. For unexplained and unknown reasons, car pools were infrequently coordinated. Each child relied on a parent/caregiver to provide passive transport. It should be noted that the journey to school might have potentially been an important opportunity for establishing daily physical activity (Tudor-Locke, Ainsworth, Adair, & Popkin, 2001). Promoting active transportation to school not only reduces an inactive behavior but potentially replaces it with moderate intensity activity (Mota et al., 2007). However, while the association between active transportation and higher physical activity has been established, conversely low socio-economic and unsafe environments have been suggested to be deterrents to active travel and predictors of passive transport (Timperio et al., 2006).

Quantity of physical activity was jeopardized in this population for a number of reasons. No school busses were available to this population due to the nature of the school system they attended. The geographic environment, surroundings, and neighborhoods of these schools prohibited most of the 55 children from playing outdoors regularly and/or walking to school secondary to safety issues and high traffic areas. Children attending school in a higher socioeconomic neighborhood were more likely to achieve the physical activity recommendations compared to those attending schools in low socioeconomic neighborhoods, even after accounting for household incomes (Crawford, Timperio, Giles-Corti, Ball, Hume, Roberts, et al., 2008). Time spent in passive transport versus active transport was overwhelming. Children who are usually driven to or from school are less likely to achieve sufficient daily physical activity, further suggesting that active transportation such as walking can contribute to overall levels of physical activity (McCormack, Giles-Corti, Timperio, Wood, & Villanueva, 2011). The great majority of this eight-year-old population relied on private vehicle transportation to get back and forth to school each day. The unsafe nature of the neighborhoods dictated that outside playtime was usually kept to a minimal for fear of drive-by shootings or abductions.

Close to 70% of the sample self-reported active, energetic play preferences yet participation, according to the accelerometer data and queries of daily play times, was fairly infrequent. Slightly less than 40% of the children admitted to any active play daily. Additionally, the majority of children stated that they did not have a regularly scheduled daily recess. Outside play was contingent on the weather and the inclination and judgment/preference of the teacher. Children spend a large percentage of their waking hours at school. The school setting has a major influence on their activity levels. Schools provide a unique venue for youth to participate in physical activity, as they serve nearly 56 million youth (National Center for Education Statistics, 2006). The rite to play and play activities are considered the most effective strategies for increasing physical activity in children. Yet, studies have shown that the majority of time spent during school recess and physical education classes are spent at low physical activity intensities (Ridgers, Stratton, & Fairclough, 2005; Wickel & Eisenmann, 2007). Additionally, the amount of time spent in moderate-to-vigorous physical activity during school hours is insufficient as it relates to the recommended amount of 60 minutes of daily MVPA (Biddle, Sallis, & Cavill, 1998).

Physical Activity Patterns

Statistically, according to the recorded counts on the triaxial accelerometer, the mean percentage of light intensity activity explained 86% this sample's daytime hours. Thirteen percent of their tempo was registered as moderate intensity and less than one percent was vigorous activity. These percentages translate into daytime hours averaging 777 minutes (almost 13 hours) of light or sedentary activity, 116 minutes (slightly less than 2 hours) of moderate intensity activity, and 6 minutes of vigorous intensity activity during the waking hours. The NHANES 2003-2004 accelerometer data was the first objective measurement of physical activity in a nationally representative health survey. The absolute count, duration and adherence prevalence results from this seven year old study presented a gloomy view of the physical activity trends in the U.S. population as a whole (Troiano et al., 2007). Although, the monitor was worn for an average of 10 hours per day rather than the average 15 hours per day worn by this sample population, the cut points for activity intensity were similar. An older generation of the motion sensor was used but the same energy prediction algorithm was utilized. If the data is averaged for comparable time durations, the trend is at best concerning.

Table 5.1 NHANES Physical Activity Data Compared to Study Participant Physical Activity Data

	Minutes in Moderate Intensity *Daytime activity*	**Minutes in Vigorous Intensity** *Daytime activity*	**Moderate-vigorous Activity bouts**
NHANES 6-11 year old Non-Hispanic black (2003-2004)	84 minutes	17 minutes	3.5 bouts
8 year old African American (2010-2011)	77 minutes	4 minutes	2.3 bouts

Secular trends demonstrate that there have been significant decreases in recess and lunchtime moderate and vigorous physical activity in young children with associated increases in sedentary time (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). Sixty-one percent of children aged 9 to 13 years old do not participate in any organized physical activity during their non-school hours; 23% of preadolescents do not engage in any free-time physical activity (Duke, 2003). Those eight-year-olds that admitted to some quantity of recess each week during their school day consistently showed less light intensity activity and more moderate to vigorous activity. For those children who claimed at least occasional recess times at school, the mean number of moderate-vigorous activity bouts was higher and the activity bout length was longer compared to those children who reported no school recess times. Adding physical activity, either in the form of enhanced physical education classes, incorporated classroom time physical movement activities, or increased recess frequency to the school day enhances and does not detract from academic performance (Rasberry et al., 2011). Even the relatively infrequent recess times allotted during the school day, there was an increased the measured number of steps and activity index per hour for those participants. Physical activity levels during recess and contributions to daily physical activity decrease as children mature and age, while sedentary time increases as active play behaviors transition to less active social behaviors (Ridgers, Timperio, Crawford, & Salmon, 2011).

The counting of steps per day is considered a simple indicator of physical activity volume that is growing in acceptance by both researchers and practitioners. The 2005-2006 NHANES data reported that children averaged approximately 13,000 (boys) and 12,000 (girls) steps per day according to accelerometer-determined steps. The use of a motion sensor is known to be more sensitive to lower force accelerations compared to pedometers. According to recently suggested cut-points/categories for steps per day, the use of actigraphy results in an increase in the reporting of sedentary activity. Table 5.2 outlines the gender-specific step-defined activity levels recently proposed. The boys in this study cohort averaged 11,007 steps per day, putting them in the low activity category according to these levels. The girls in this study cohort averaged 10,985 steps per day, placing them in the somewhat active category.

Table 5.2 Step-defined Activity Levels

Activity Level	Boys 6-11 yrs	Girl 6-11 yrs
Sedentary	<10,000 steps	<7,000 steps
Low active	10,000-12,499 steps	7,000-9499 steps
Somewhat active	12,500-14,999 steps	9,500-11,999 steps
Active	15,000-17,499 steps	12,000-14,499 steps
Highly active	≥17,5000 steps	≥14,5000 steps

(Tudor-Locke, Johnson, & Katzmarzyk, 2010)

Setting appropriate energy cut-points for health-related physical activity is hampered by imperfect assessment of this behavior. Recent secondary analysis of an existing international database was used to establish BMI-referenced standards for pedometer-determined physical activity in youth. Girls that took < 12,000 steps per day and boys that took < 15,000 steps per day were more likely to be classified as overweight or obese (Tudor-Locke, Johnson, & Katzmarzyk, 2010). Although these BMI-referenced steps per day cut-points appear higher than previously suggested, it is not inconsistent with insight of the physical activity needs of children.

Physical activity intensities were varied over a twenty-four hour period when compared to amount of time spent viewing entertainment media/screen time. Over 70% of the children self-reported more than 2 hours of screen time per day and over 50% of the sample described greater than five hours of after school television time alone. Extended screen time after school hours added to the sedentary behavior of the sample. This verifies the findings from another recent study that found children who spent more than two hours a day on screen-based activities took significantly fewer steps per hour and were less likely to achieve the daily activity cut-points (McCormack, Giles-Corti, Timperio, Wood, & Villanueva, 2011). The mean percentage of light intensity physical activity in a day's time decreased with a reduction in the screen time. The moderate to vigorous intensity was higher when the screen time was less than five hours per day. Activity bouts were seen to be highest in number and length with the least amount of screen time per twenty-four hour period. Steps per day and activity index per day were highest with the least amount of screen time per day. Of the 70% of the children reporting greater than two hours of screen time per day, close to half ate dinner alone in front of the television. Although, energy intake was not a variable in this research, ecologically the balance of daily energy is impacted subtly by a variety of correlates. A significant proportion of a child's daily energy is consumed during television viewing. The consumption of high-fat foods during television viewing on weekdays has been shown to be significantly correlated with body mass index in third graders (Matheson, Killen, Wang, Varady, & Robinson, 2004). Media use has increased to a reported 28% of youth watching more than 4 hours of television per day while approximately 27% of 5-6 year olds use the computer for an estimated 50 minutes per day (Anderson, Crespo, Bartlett, Cheskin, & Pratt, 1998). NHANES data states that an estimated 25% of children between the ages of 4-11 years watch more than 3 hours of television/day (Anderson, Economos, & Must, 2008; Marshall, Forely, & Biddle, 2006). The American Academy of Pediatrics suggests limiting total media time to no more than 1-2 hours of media time per day (American Academy of Pediatrics, 2001). Research verifies the significant, inverse relationship between screen time and correlates of physical activity, suggesting possible evidence for a displacement hypothesis (Marshall, Biddle, Gorely, Cameron, & Murdey, 2004). The majority of the children in this cohort claimed that they spent their free time out of school in front of some type of entertainment media screen, usually a computer or a television.

Sleep Pattern

The agreement for actual sleep time and nocturnal wake time between actigraphy and diary data has been shown to be insufficient in prior studies (Werner, Molinari, Guyer, Jemni, 2008). The objective monitoring of sleep in this study focused specifically on the characteristics of night time sleep duration, the number of wake episodes at night, and the duration of the night wake episodes. The eight year old subject participants were not consistently reliable record keepers when asked to record the time to bed at night and the time out of bed in the morning. It was incomplete and markedly inaccurate. Additionally, time in bed as reported by parents proves to underestimate sleep duration as compared to objectively measured actigraphy (Nixon, et al., 2008). For this reason, sleep latency was not measured. The exact time to sleep was designated as the beginning of a series of zero counts on the motion sensor. Sleep start time was defined as at least three consecutive minutes of sleep and the sleep end time was defined as the last five consecutive minutes of sleep (Acebo, Sadeh, Seifer, Tzischinsky, Hafer, & Carskadon, 2005). This method proved to be the most reliable process for determining precise sleep times in this sample.

Average sleep time per night was incredibly variable but objectively measured as a mean of 483 minutes of sleep per night, or approximately 8 hours per night. According to the CDC recommendation of 10-12 hours of sleep per night, this lack of sleep qualifies as sleep deprivation in this sample (CDC, 2011). Twenty-five percent of these eight year olds stated that they did not sleep in a consistent spot each night and claimed that they slept either on a sofa, with different relatives, or on the floor. The mean number of wake episodes for this sample was 20 times per night with an average wake time per episode of slightly over four minutes. The children who slept in a consistent location had slightly more wake episodes with shorter, wake episodes.

Night awakenings are a common sleep pattern in infants and toddlers and one that is typically outgrown as a child matures. Sleep studies with school-aged children show a prevalence of nightwakings to be an estimated 15-20% (Mindell & Owens, 2005). Difficulties with sleep maintenance occur for many different reasons, but persistent and prolonged nightwakings are most commonly related to inappropriate sleep onset associations. Parental presence at bedtime is the strongest predictor of disrupted sleep patterns and is associated with increased nightwaking and reduced total sleep time (Mindell, 2005). Approximately 30% of school-aged children reported falling asleep with a parent present; this practice was associated with a six-fold increase in the likelihood of nightwakings (Mindell, 2005). Other differential contributors and/or diagnosis for these arousals could relate to a biological correlate, such as obstructive sleep apneas, or environmental factors, such as parent-child interactions or unsafe, unfavorable physical settings (Morgenthaler et al., 2006).

Weight Status

The prevalence of combined overweight and obese eight-year-olds in this sample is 55%. The prevalence of exclusively obese eight-year-olds in this sample is 35%. The national obesity prevalence for 6-11 year olds according to the 2007-2008 NHANES is 19.6%. This is the highest national percentage rate since data collection began in the 1960's and can be seen precisely and dramatically in the graph and table below. According to the CDC parameters outlined in Table 3.2, 35% of this cohort is obese (68% girls / 32% boys), 20% of this sample is overweight (73% girls / 27% boys), and 45% are normal or underweight (56% girls / 44% boys). The gender differences in this cohort are not consistent with national trends. According to the CDC Health7 Obesity report, boys steadily have a higher percentage of obesity/overweight. However, for the first and only time, in 2007–2008, there was no statistical difference seen between boys and girls in the percentage of children who were obese.

Table 5.3 NHANES Trends of Obesity 1963-2004

	NHANES 1963-1965	NHANES 1971-1974	NHANES 1976-1980	NHANES 1988-1994	NHANES 1999-2000	NHANES 2001-2002	NHANES 2003-2004
Prevalence obesity (6-11 years)	4.2%	4.0%	6.5%	11.3%	15.1%	16.3%	18.8%

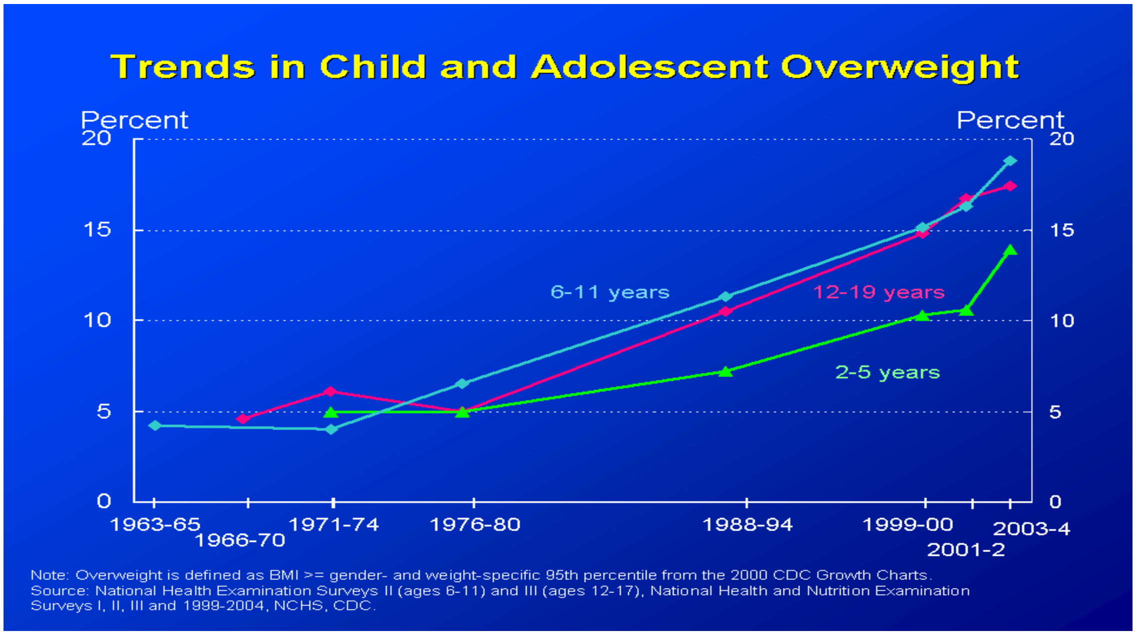


Figure 5.1 NHANES (CDC) Obesity Trends

Despite the statistical fact that the national frequency of preteen obesity and overweight has increased so dramatically nationally, the incidence of obesity in this particular sample population is 179% over and above the national average for this specific age group.

A comparison of free-time activity varied according to the stratified weight categorization of these eight-year-olds. The incompatible nature of daily play frequency and screen time is evident in this study. Findings showed that the more time spent in front of an entertainment screen, the smaller the amount of time spent in daily play time, across all weight classifications (McCormack, Giles-Corti, Timperio, Wood, & Villanueva, 2011). Less than 50% of the children in this study, in every weight group, actually reported watching less than two hours of screen time per day. Additionally, less than half of these 8-year-olds self-reported spending time playing every day. There appears to be a graded association between level of moderate physical activity and risk of overweight among children who watch more than four hours of television per day (Eisenmann, Bartee, Smith, Welk, & Fu, 2008). A statistically significant relationship has been shown to exist between television viewing and body fatness among children and youth (Marshall, et al., 2004).

Academic Performance

Academic scores were evaluated by two distinct techniques: teacher evaluations and standardized tests. The evaluations offered by the third grade teachers were essentially pass/fail with subjective comments depending on the student and the persona of the teacher. The standardized tests (Michigan Education Assessment Profile) were offered over several days in the fall of their third grade year by the state of Michigan. This was the first time these students were included in the standardized testing process. The two areas tested were mathematics and reading. The scores were leveled for proficiency rankings. Levels 1 and 2 were considered to be proficient and passing. Levels 3 and 4 were equated with not proficient and failing. Eighty-six percent of the sample students were passing the third grade as scored by the teachers three quarters of the way through the academic school year. The grades/evaluations assigned to the students by the third grade teachers significantly correlated with the proficiency levels attained in the standardized tests. Additionally, the Michigan Educational Assessment Profile for these three charter schools corresponded fairly closely with the average third grade scores throughout the state. Level 1 and 2 mathematics proficiency levels were 94% and 95% as recorded from the charter schools and the state, respectively. Level 1 and 2 reading proficiency levels were 86% and 87% as documented by the charter schools and the state, respectively. A major distinction between the Level 1-2 and Level 3-4 reading and mathematics proficiency groups was the amount of screen time per day. The majority of Level 1-2 mathematics and reading children watched less than two hours of screen time per day; Level 3-4 mathematics and reading children watched more than two hours of screen time per day. A noticeable difference between the reading and mathematics proficiency level students was the daily play time. Level 1-2 mathematics students claimed daily play time; Level 3-4 mathematics children did not report daily play time. This difference was not applicable for the reading proficiency levels.

Assessments to determine associations between lifestyle behaviors in children (screen time and play time) and academic outcomes allow school districts to make informed decisions to promote learning. Quasi-experimental interventions have shown that time spent in physical education and activity during the school day does not diminish academic grades or standardized scores (Trudeau & Shephard, 2008). The relationship of selected physical fitness measurements and standardized academic scores in grade schoolers was recently compared in a cross-sectional study. Vigorous physical activity and reduced television time was found to be significantly associated with higher standardized mathematics and reading scores (Edwards, Mauch, & Windelman, 2011). Conversely, an increase in television and computer screen time has been found to increase the odds of receiving poorer teacher academic reports (Sharif & Sargent, 2006). Additionally, it has been shown that parental restriction of televison time resulted in increased time spent reading and doing homework and subsequently higher academic grades (Wiecha, Sobol, Peterson, & Gortmaker, 2001).

Academic Behaviors

The attendance record for this sample was of significant concern to the teachers and the administration. Absenteeism approached an extravagant 10% average of available school days missed. Tardiness was too abundant to track in this study. Indeed, according to the third grade teachers, truancy was not an unusual or unexpected situation at these schools.

A small contribution to the picture of absenteeism may have been illness or disease. One chronic disease condition, asthma, was reported by the students and verified by the phone calls home to the parents/caregivers. Asthma required periodic medications and was responsible for only a few missed school days in merely 5% of the sample. Failure of passive transportation arrangements was the major contributory cause to the lack of attendance or tardiness on many of the scheduled school days, according to school staff. The commitment to drive the children to school was reportedly all too frequently vacated by other allegiances.

Physical Activity and Sleep Correlations

Light intensity physical activity and sleep are both low energy-expending activities, increased time in sedentary behaviors and increased time spent sleeping have opposite effects on a child's weight status (Must & Parisi, 2009). Sedentary behavior has increased and sleep volume has decreased in today's youth (Must & Parisi, 2009). The relationships between several of the physical activity dimensions and sleep characteristics in this research are intriguing. The summary table below displays them most clearly.

Table 5.4 Physical Activity and Sleep Associations

	Activity Bouts/day	**Percent Light Activity/day**	**Percent Moderate Activity/day**	**Steps/day**	**Activity Index Counts/day***
Length Wake Episode/night				*Negatively correlated*	*Negatively correlated*
Frequency of Wake Episode/night	*Positively correlated*	*Negatively correlated*	*Positively correlated*		
Sleep	*Negatively correlated*				

* Vector Magnitude

Wake episodes (nighttime arousals) are defined as transient changes in the activation level within a sleep episode (Salzarulo, Giganti, Fagioli, & Ficca, 2002). Most children wake up at least a few times a night. The difference among 'normal' and 'problem' sleepers is whether the child decides/needs to signal/awaken an adult for assistance. In this research, wake episodes were counted by actigraphy and averaged for length and frequency per night over 2 second epochs and smoothed to 60 second epochs. Wake episodes per the actigraphy were seen as increased activity intensity and logged according to the Sadeh sleep algorithm (Sadeh, Lavie, Scher, Tirosh, & Epstein, 1991). The average length of wake episodes during the night was strongly, inversely correlated with the frequency of wake episodes during the night.

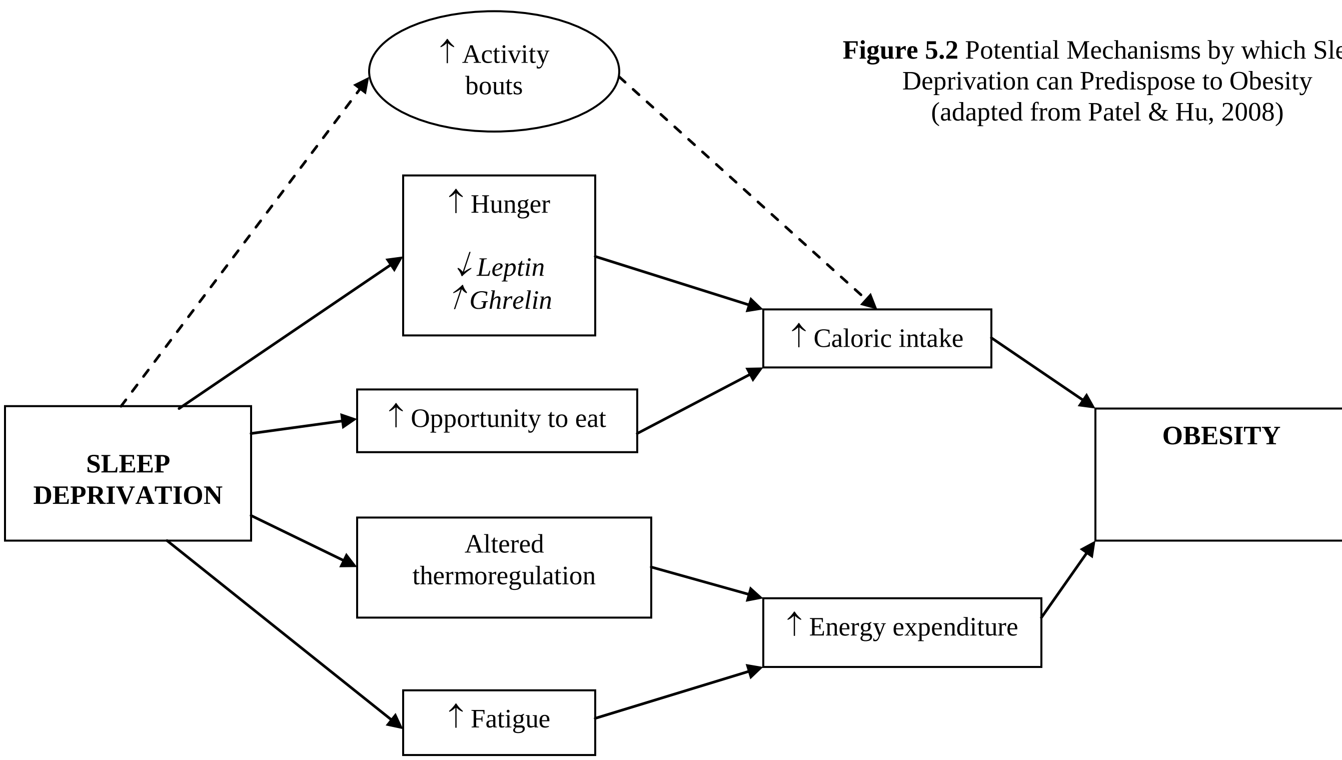
The average wake episode length was also inversely related to the number of steps per hour and the daily activity index. Actigraphy provides an estimation of energy expenditure and is the cost of physical activity behavior. A function of sleep is to conserve this energy. However, sleep deprivation increases energy expenditure indicating that maintaining wakefulness under bed-rest conditions is energetically costly (Jung et al., 2011). Small differences in energy expenditure have been observed among sleep stages, but wakefulness during the sleep episode has been associated with increased energy expenditure (Jung, et al., 2011). The increase in the length of wake episodes during the night and decrease in hourly steps and activity index may be explained by the finding that wakefulness during the sleep episode is associated with increased energy expenditure, consequently allotting less energy for daytime activities (Jung et al., 2011). Additionally, longer wake episode length after sleep onset was highly associated with reduced sleep quality and negative school performance (El-Sheikh, Buckhalt, Cummings, & Keller, 2007; Meijer & van den Wittenboer, 2004).

The frequency of wake episodes however shows some interesting associations. A recent longitudinal study, in which parents reported the sleep durations and habits of their children, revealed that the number of night wakings of preschool children had little impact on sleep duration (Petit, Touchette, Tremblay, Boivan, & Montplaisir, 2007). Yet, school-aged children with fragmented sleep, as based on actigraphic estimates of night waking, showed lower performance on neurobehavioral functioning measures as well as an increase in behavioral problems (Sadeh, Gruber, & Raviv, 2002). Sleep is a time-based cumulative process that can be impeded by biological disorders as well as environmental disturbances. Brief periodic arousals from sleep reduce the restorative power of sleep and leave deficits similar to those seen after total sleep deprivation (Stepanski, 2002). Sleep also has an identified sleep stage architecture. When sleep is disrupted, each arousal causes the process to start over, causing loss of needed sleep. In this research sample, the actigraph estimated nocturnal wake time was eighty minutes per child per night. Prior studies have shown an estimated actigraph value of sixty minutes of wake time in children thirty months and older (Acebo, Sadeh, Seifer, Tzischinsky, Hafer, & Carskadon, 2005). The reason for the high accumulation of wake episodes can only be assumed in this study; the scope of this research limits the cause to speculation.

The lifestyle patterns of family members, the close living quarters, the environmental city noise, and the size of children may all add to the higher frequency of wake episodes. As this sample was being studied within the Bioecological framework, it is significant to note that family socioeconomic status has been found to be a significant contributor to sleep/wake patterns (Acebo, Sadeh, Seifer, Tzischinsky, Hafer, & Carskadon, 2005). Children in families with lower socioeconomic status had more nocturnal waking and higher night time variability. Additionally, since nighttime waking in children has aptly been termed “A Disease of Civilization”, it is also important to consider factors that may trigger night arousals, such as a noisy or stimulating environments, especially where safety is an issue and where consistent sleep arrangements are not always a reality (Trilling, 1989).

In addition, it is worth noting that short sleep duration appears to be independently associated with weight gain, particularly in children (Patel & Hu, 2008). The pediatric data suggests that the relationship between sleep duration and weight may actually weaken with age (Gangwisch, Malaspina, Boden-Albala, & Heymsfield, 2005). Evidence has grown over the past decade supporting the role of short sleep duration as a novel risk factor for increased obesity (Chaput, Brunet, & Tremblay, 2006; Chen, Beydoun, & Wang, 2008). A concise overview of the proposed causal pathways is diagrammed below in Figure 2 (Patel & Hu, 2008). (The circular item in Figure 2 is the increase in activity bouts that was found to have a weak negative correlation with sleep duration in this study.) Given the lack of interventional trial data, however, the possibility of reverse causation (obesity increases the risk of medical conditions that can disrupt sleep) is another concern. Obesity is the strongest risk factor for obstructive sleep apnea which has as its hallmark disruption of sleep (Young, Peppard, & Gottlieb, 2002). Since 55% of this sample is overweight and/or obese, obstructive sleep apnea cannot be excluded as a contributory factor to the high frequency of nighttime arousals.

Figure 5.2 Potential Mechanisms by which Sleep Deprivation can Predispose to Obesity (adapted from Patel & Hu, 2008)



The prevalence of these wake episodes, as seen in Table 5.4, is inversely related to the percent of light intensity activity during the daytime and positively related to daily moderate intensity activity and average moderate-vigorous intensity bouts. The objective measure of sleep characteristics in children with the use of home actigraphy is relatively new. The underlying mechanisms of wake episodes and moderate activity (either daily percentage of or in the form of an activity bout) warrants further study. Explanation of why an increase/decrease in nighttime wakings would correlate with the same direction of increase/decrease in moderate physical activity might be found through further research studies. It may be realized as a utility in the sleep fragmentation or a function of sleep deprivation in young prepuberty children. It is unclear whether the significant function is frequency of night wakings or length of night wakings (Velten-Schurian, Hautzinger, Poets, & Schlarb, 2010). With an inverse relationship between night wake episodes and light daytime activity, the implication and meanings of wake episodes in children is ambiguous. Increased light intensity activity or sedentary activity is correlated with a decrease in the frequency of night wake episodes. The balance of energy expenditure warrants further study. The consequences of night wake episodes in children appear perplexing. Many behavioral factors have been studied in relation to nighttime wakenings or arousals but no causal associations have been realized to clarify the relationship between night time wakings and daytime activity intensities. No known associations between the number of nighttime wake episodes and physical activity intensities have been found in the research literature. The correlations noted are weak and not in the direction expected. Additionally, these may possibly be considered spurious correlations.

The number of moderate-vigorous intensity activity bouts is negatively and significantly correlated with the hours of sleep per night. In other words, shorter nighttime sleep was associated with an increase in activity bouts per day. It is important to understand that the activity bouts in this study were measured as five minute bouts of moderate-vigorous activity (according to age-specific energy expenditure predications) with a one minute drop or tolerance time. It is also important to appreciate that there was no correlation seen between percent/day of moderate or vigorous intensity activity and sleep duration. The inverse relationship between duration of sleep and number of activity bouts may actually describe an activity pattern of a sleep deprived child, given the short sleep duration of this sample. Activity bouts in this study averaged 2.3 episodes of four to five minute bouts. The frequency of these activity bursts increased with less sleep hours. Further research is needed to inform what aspect of a child's activity pattern is related to health. For instance, it is known that short, intense bursts of activity are important for bone health (Rowlands, Pilgrim, & Eston, 2008). The function of activity bouts– the needed intensity, the bout frequency needed, and the required length of the bout warranted– are all components needed to complete the dose response between activity and health outcomes.

The relationship between sleep duration and patterns of physical activity has not been thoroughly researched. Sleep and physical activity are typically studied in the arena of obesity or body weight. Studies on the effect of daytime physical activity on sleep duration have shown variable results (Nixon et al., 2008). One research study that used secondary analysis of a large cross-sectional Spanish study reported that insufficient night time sleep and morning tiredness substantially reduced the likelihood of participating in any leisure-time physical-sporting activities (Ortega et al., 2010). Another study of children aged 5-15 years of age, through the analysis of self-reported data collection, informed of a significant association between short sleep duration and ranges of physical activity intensities (Shi et al., 2010). Several other studies have deduced that low levels of physical activity added an additional risk of obesity to short sleep duration (Patel, Malhotra, White, Gottlieb, & Hu, 2006; Shi et al., 2010). Another recent study concluded that adjustment for physical activity and inactivity weakened the association between sleep and BMI (Carter, Taylor, Williams, & Taylor, 2011). The different methodologies are often credited with the reason for differing results. Duration or type of exercise has been shown to only have a weak impact on total sleep time, unless the exercise was prolonged for greater than one hour (Youngstedt, O'Connor, & Dishman, 1997). A study in adults using actigraphy-quantified exercise found no correlations between physical activity and sleep duration (Youngstedt, Perlis, O'Brien, Palmer, Smith, Orff, et al., 2003). Recently, another study revealed that children who slept less than nine hours spent more time in sedentary activity yet, they did not do any less moderate or vigorous activity despite presumably being more tired (Nixon, et al., 2008). The unknown factor in this energy balance between sleep duration and physical activity bouts may be that the length of the exercise rather than the intensity. In addition, possibly the critical element or variable to monitor may not necessarily be the moderate to vigorous activity but the quantity of sedentary activity that impacts sleep. Further quantitative studies are needed to determine the actual variables of interest and the impact on health outcomes.

Physical Activity and Weight Correlations

According to the correlational analysis there was no relationship between the measured BMI (surrogate measure of adiposity) of the students and the objectively measured dimensions of physical activity. The fundamental physiological cause of accumulated excess body fat is an energy imbalance between energy intake and energy expenditure. Accordingly, it has been suggested that an increase in energy expenditure, as a consequence of increased physical activity, is important in maintaining energy balance and protecting against excess weight gain. There is compelling evidence for a strong inverse relationship between body weight and physical activity in children as seen in a recent systematic review. Seventy-nine percent of the studies examined supported the hypothesis that higher levels of habitual physical activity are protective against childhood obesity (Jimenez-Pavon, Kelly, & Reilly, 2011). Specifically, vigorous physical activity levels only have been associated with body fatness during the adiposity rebound period of adolescents (Janz et al., 2002; Vale et al., 2010).

However, several other reviews of prospective accelerometry studies concluded that low levels of baseline physical activity were only weakly associated with adiposity gain and that measured physical activity was not strongly related to change in adiposity (Hawkins & Law, 2006; Must & Tybor, 2005; Wareham, van Sluijs, & Ekelund, 2005;Wilks, Besson, Lindroos, Ekelund, 2010). Conclusions drawn from these reviews concurred that physical activity was not the main determinant of unhealthy weight gain. Low levels of physical activity were considered to be only weakly correlated with the predisposition to obesity in children. The correlational design of most of these studies impedes the interpretation of results. Recent inquiry regarding the potential efficacy of reverse causality has encouraged additional prospective meta-analysis of studies. A higher body weight/adiposity may lead to a lower physical activity level; in other words, a reduction of physical activity may be the result of a high level of adiposity (Kwon, Janz, Burns, & Levy, 2011; Wilks, et al., 2011). A high level of adiposity may negatively influence physical activity participation by children presumably through psychological, societal, and physical functioning. Meta-analysis with novel bias-adjustment allowed a quantitative evaluation of the prospective relationship between physical activity energy expenditure and change in percent body fat in children and showed no significant association (Wilks, et al., 2011).

Additional previous studies using pedometers to assess physical activity also failed to observe significant differences between obese and non-obese children (Romanella, Wakat, Loyd, & Kelly, 1991; Wilkinson, Parkin, Pearlson, Strong, & Sykes, 1977). The results showed that there was no significant difference between the energy intake and the measured activity of the obese children when compared to the normal weight children. In a seminal study from 1977, it appeared that the ranges of energy intake and exercise were wide but there was a tendency, for above average intake to be associated with above average activity (Wilkinson, Parkin, Pearlson, Strong, & Sykes, 1977).

It is difficult to combine study results secondary to differences in study designs, sample populations, and/or inquiry methods. Accelerometers have been considered the "gold standard" in free-living physical activity assessment. They provide a relatively reliable and valid estimate of energy expenditure from physical activity and quantify the amount of time spent in moderate-vigorous activity (Pate, O'Neill, & Mitchell, 2010). Yet, the wide variation in study results indicates that no clear picture can be drawn regarding the typical physical activity levels in a sample population and caution needs to be exercised when interpreting pooled estimates. The differences in cut-points preclude the ability to draw sound conclusions about accelerometer-derived estimates of activity (Bornstein, Beets, Byun, & McIver, 2011). The Freedson equation was used in this research for two reasons. The prediction equation was age-specific and there is known to be energy expenditure differences according to age. Also, the Freedson equation was the equation most used by the ActiGraph accelerometer (the most used accelerometer in research with children) and thus consistency across studies could be appreciated. This equation as been shown to have the highest cutpoints for moderate-vigorous activity, yet the age specification will enable the increase cutpoints in energy, allowing more accuracy in predictions.

Low levels of physical activity have been mentioned as potentially modifiable factors that increase the risk of overweight in childhood (Trost, Sirard, Dowda, Pfeiffer, & Pate, 2003). While the total amount of time per day engaged in sedentary behavior is inevitably prohibitive of physical activity and the cumulative effect of multiple sedentary behaviors reduces total energy expenditure, relationships between sedentary behavior and health are unlikely to be explained using a single marker (Marshall, Biddle, Gorely, Cameron, & Murdey, 2004). Body weight is influenced by many ecological correlates. Although physical activity is associated with health benefits in school-aged children, the dose-response relationship between activity dimensions and weight remains elusive. Relatively little is actually known about the precise relationship between various levels of physical activity intensity and body weight

Physical Activity, Academic Achievement and Academic Behavior Correlations

Regular school attendance is a necessary part of the learning process. Student absenteeism has a direct association with poor academic performance and individual long-term social and economic repercussions (Weismuller, Grasska, Alexander, White, & Kramer, 2007). Attendance (number of school days missed) and rate of absenteeism (percent of missed days per child) were positively and significantly correlated with light intensity physical activity; the more days absent the more light intensity activity was recorded. However, as one would expect, there was an inverse significant association between the number of days missed and the moderate intensity activity, moderate-vigorous activity bouts, number of steps taken per day, and vector magnitude counts per hour. The more active child registered more activity on the accelerometer and missed less school days.

The number of moderate-vigorous activity bouts was significantly and positively correlated with the standardized MEAP test in the area of reading only. This same relationship was not seen with the standardized MEAP mathematics test. In other words, statistically, the better readers were more active as seen by the number of moderate-vigorous activity bouts per day in this study. Cognitive studies are warranted to determine what areas of the brain are most affected by physical activity and what areas of the brain are used for reading skills as opposed to mathematics skills. There is accumulating evidence of a significant positive relationship between physical activity and academic-related outcomes and overall school performance and behavior (Castelli, Hillman, Buck, & Erwin, 2007; Chomitz et al., 2009; Eveland-Sayers, Farley, Fuller, Morgan, & Caputo, 2009; Hillman, Castelli, & Buck, 2005; Sibley & Etnier, 2003; Wittberg, Cottrell, & Northrup, 2009). Specific subject matter has not yet been researched as it relates to various physical activity intensities and duration.

School sports is a complex phenomenon and worth mentioning since such a large percentage of a child’s time is impacted by school activities. There are many cultures and ecological influences within school sports to include race, gender, type of sport, and type and level of involvement. A survey was conducted to examine the extent to which participation in different kinds of sports in Ontario had consequences for educational attainment in the Canadian school system (White & McTeer, 1990). Participation in the status of a given sport (High status sports were considered to be golf and tennis.) had a positive influence on English grades, yet there were no relationships reported between sports participation and grades earned in mathematics. The conclusion drawn from this research was that academic achievement was more likely to be affected by cultural factors in subjective areas like English rather than in mathematics (White & McTeer, 1990). The sample population in this research was overwhelmingly African American and none of them participated in school sports. The association between reading scores and moderate-vigorous physical activity bouts persisted.

Increased physical activity as it relates to the academic domain is important for several reasons. Increased physical activity has beneficial health effects and according to this research is associated with less absenteeism. Additionally, increased activity is correlated with increased reading aptitude. Despite the facts that this sample population has a statistically high light intensity activity profile, the reading scores were still positively associated with a modest amount of increased moderate activity.

Activity-Sleep and Pass-Fail

Reading Grades Students with failing reading grades as compared to the students with passing reading grades had the following profile. The failing students had more school days missed and more light intensity activity than those with passing reading grades. In addition, the students with failing reading scores were significantly less active as evidenced by less daily moderate intensity activity, steps taken per hour, and vector magnitude counts per hour. Evidence indicates that physical exercise and fitness are related to better working memory in children (Barratt, Tugade, & Engle, 2004; Buck, Hillman, & Castelli, 2008). All the studies with reported positive relationships between physical activity and academic-related outcomes used standardized assessments to measure the scholastic outcomes (Efrat, 2011). In recent research, moderate-vigorous physical activity was found to be positively associated with better mathematics and reading scores, but merely participating in physical education instruction, was not associated with these superior scores (Stevens, To, Stevenson, & Lochbaum, 2008). In an ecological frame, dose-related physical activity (type, intensity, frequency, and duration) can influence the relationship between physical activity and academic achievement in many arenas, especially among low-income, minority children (Efrat, 2011). Without the after school athletic programs, the enhanced community centers, or the outdoor safety stipulations, socioeconomic influences will confound the association between physical activity opportunities and academic success.

Mathematics Grades The profile of the students with failing mathematics grades, as delivered by the teachers, was slightly different than the profile of the failing reading students. The students that were failing mathematics had significantly longer wake episodes at nighttime than those students who were passing mathematics. Several studies have shown that sleep loss is associated with cognitive impairments in children (Nixon et al., 2008; Sadeh, Gruber, & Raviv, 2003; Touchette et al., 2007). The profiles between the passing/failing mathematics students and the passing/failing reading students are distinctly different. In a homogenous sample, without sociocultural confounders, this may highlight more than academic consequences to lack of sleep but instead may accentuate fundamental dissimilarity in the mechanism of learning per subject matter.

Relationship of Sleep, Weight, and Academic Variables with Physical Activity

Canonical correlation analysis was used to determine if the set of physical activity dimension variables was related in any way to the set of demographic variables, and the major study variables of sleep characteristics, weight status, and academic variables. This analysis was used to assess the overall relationships of the above cited canonical variates as well as the relative importance of the associations to each other. Light intensity activity and moderate intensity activity were the most important criterion variables. Hours of sleep, number of days absent from school, and number of wake episodes per night were the most essential predictor variables, followed by BMI and average length of wake episodes per night.

Daytime percentages of light and moderate intensity activity are important considerations when evaluating the average hours of sleep per night, as well as the frequency and length of wake episodes during the night. Although the connection between sleep duration and inactivity/activity behavior of children has been consistently suggested in the literature, there is little empirical data to support this relationship. Until recently, the available information between sleep duration and inactivity behaviors has been based mainly on self-reported episodes of daily screen time or bedtime habits. The relationships have typically suggested that short sleepers have a higher percentage of daily sedentary time. However, the research has lacked objective data. Recently, inquiry that informed the association between sleep duration and activity levels was published. A contemporary study used actigraphy for the objective collection of sleep data and then subsequently controlled for age and sexual maturation. The association was greatly attenuated after controlling for the confounders but continued to show significance between sleep and activity. The main finding of this research explained that individuals with longer hours of sleep duration spent more time in all intensities of daytime physical activity (Ortega et al., 2011). Yet the literature on sleep duration and physical activity is fairly limited and often contradictory. Some studies have demonstrated that children who slept less were more physically active (Wells et al., 2008). Self-reported leisure time activities showed no association with sleep duration after adjustment for age (Van den Bulck, 2004). An objective collection of data, using wrist accelerometers to measure sleep duration and total activity patterns over a 24 hour period, failed to find an association between sleep duration and total physical activity in adolescents (Gupta, Mueller, Chan, & Meininger, 2002). Although the above accumulation of listed studies offers a conflicting association between sleep duration and various levels of physical activity, the research does tend to support the relationship between sedentary times and sleep duration.

Objective data on pivotal sleep-related variables, such as arousal or wake, endorse that one function of sleep is to conserve energy. Research has recently been conducted examining the amount of energy conserved by sleep, the amount of energy expended when a night of sleep is missed, and how much energy is conserved during recovery (Jung, et al., 2011). The sample used in this current study empirically displays sleep deprivation as evidenced by the consistent inability to maintain sleep across the night. Sleep deprivation has been shown to increase energy expenditure indicating that maintaining wakefulness under bed-rest conditions is energetically exorbitant. Recovery sleep has been shown to be energy effective, possible by reduction in arousals, suggesting that one's metabolic physiology may be able to make adjustments in response to the energy cost of sleep deprivation (Curcio, Ferrara, Pellicciari, Cristiani, & DeGennaro, 2003; Jung, et al., 2011). Yet, sleep duration differences between weekdays and weeknights were not significant in this sample. Make-up time/recovery time was not a confounder in this study.

School attendance and weight status share a variance relationship with light and moderate physical activity. Sedentary behavior or light intensity physical activity is cross-sectionally correlated with obesity in children as well as being a risk factor for the development of obesity in children (Gortmaker et al., 1996). Recent research targets the interventional consequences of decreasing sedentary behavior in children (Epstein, Roemmich, Cavanaugh, & Paluch, 2011). Weight change is not simply associated with changes in physical activity when sedentary behaviors are reduced. The bio-ecological theory expands upon the realm of influence to include situational incentives and environmental stimuli that potentially modify behaviors. The motivation to be sedentary is a behavioral phenotype. An enhanced understanding of factors related to the relationships between changes in sedentary behavior and energy balance behaviors and weight loss through the specifics of ecological levels could improve our interventional endeavors.

Additional Findings

Sleep

In an effort to more precisely identify factors and correlates that may contribute to a better understanding of the obesity epidemic in children; a profile per weight category was configured using one-way analysis of variance. For the sake of clarity, the weight classifications were consolidated into three categories, obese, overweight and normal weight. The three underweight children were included in the normal weight category. Hours of sleep and dimensions of physical activity were included in the analysis. The only area of significant difference among the three groups was duration of sleep. The children in the obese class slept 32.5 minutes less than the normal weight children and the overweight class slept almost 46 minutes less than the normal weight children and 13 minutes less than the obese children. Numerous reports of weight gain associated with chronic partial sleep deprivation exist. A meta-analysis study of short sleepers (children sleeping less than 10 hours/night) found a consistent, increased risk of obesity, suggesting that reduced sleep duration is associated with larger body mass (Cappuccio, et al., 2008). Due to the cross-sectional design of the study, one is not able to determine if the shorter sleep duration is a result or a consequence of the weight status. The only absolute determination was that sleep duration, not any of the physical activity dimensions, was significantly related to the weight status. Continued analysis of the specific categories of weight according to obese/overweight and normal/underweight only confirmed the finding that weight status is significantly correlated with only the variable of sleep duration.

Weight Correlates

Despite the finding that there was no significant correlation between physical activity dimensions and weight status, closer examination was performed according to the three weight classes of obese, overweight, and normal weight. The physical activity profile of an obese child revealed that light activity intensity was significantly and inversely correlated with moderate intensity activity, vigorous intensity activity, and moderate-vigorous activity bouts. This specific profile was not seen in the other two classifications of overweight and normal weight. The profile of the overweight child uniquely showed light activity was significantly and inversely correlated with moderate intensity activity, moderate-vigorous activity bouts, and steps/hour. According to previous studies, daily step count suggests valid information on daily physical activity for preschool children (Tanaka & Tanaka, 2009). The normal weight child showed none of these relationships. These findings may assist in tailoring physical activity interventions for different weight classifications. The 'one-size-fits-all' approach seems to be failing miserably in effectiveness. The findings here may instead suggest that the overweight children benefit from taking more steps/hour while the obese children may be more influenced by bouts of vigorous activity. Controlled research trials are necessary in these explicit areas to expand the success of interventional studies.

Implications

Implications for Bioecological Framework

The Bioecological perspective involves the progressive and mutual accommodations between a growing individual and the changing properties of their environment. It is founded on two basic assumptions. First, the child's development is influenced by both biological and cultural factors, and second, development depends on other people. A Bioecological study investigates these progressive modifications between a growing child and his/her surroundings through systematic comparisons. One of the primary focuses of a Bioecological framework is to concentrate attention on environmental impacts on behavior and then to subsequently identify environmental interventions. The ecological paradigm has many moving parts with multiple levels. Working within an ecological model requires that measurement and assessment take place at more than one level. In the Bioecological research, the principal findings are likely to be interactions that enable the systematic analysis of the fit between the environment and the individual. An individual and his/her surroundings are not static, thus there must be allowance for these evolving processes of interaction.

Detection of wide-ranging developmental influences becomes possible only if one employs a theoretical framework that permits them to be observed. Important to behavior and maturing is the environment as it is perceived rather than as it may exist in objective reality. Although the constructs in this study were objectively measured and analyzed, it is important to remember that the perceptual views are diverse. The concepts of health and psychosocial indicators were epitomized as the objectively measured constructs of physical activity dimensions, sleep characteristics, weight status, academic achievements and academic behavior. The multilevel framework was considered in a low socio-economic urban setting with a homogenous cohort. Despite sample similarities, retrieval of qualitative information was assorted, experiences were varied, perceptions were distinctly dissimilar, and health outcomes markedly divergent. Interventional effectiveness would lack successful execution without tailoring strategies. The implementation of a walking program for the obese eight-year-old in this sample may not be as effectual as instituting a series of moderate-vigorous activity bouts. On the other hand, the overweight eight-year-old may excel physically with a pedometer/daily step challenge. The lack of outdoor play impacts the extended screen time in this population which shapes their sedentary activity. An intervention could effectively be manipulated around controlled, indoor after school activities. The poor reading grades in the school are influenced by the proximally prominent home situation in the ecological model. The proximal processes are the primary engines of development and are not unidirectional. The family living situation and the school setting play not only a very significant role in a child's development but a reciprocal role as well. The high percentage of passive transport in this community impacts the high percentage of sedentary activity as well as the significant school absenteeism which is correlated with the poorer reading scores.

Individuals and families are influenced by their environment and mutually influence and change their environment through the process. The development and maturity of an individual is a continuous relational process of interactivity with their environment. Relational processes require the bidirectional linkage with health indicators and psychosocial indicators. The operational research design for the Bioecological frame is the Process-Person-Context-Time (PPCT) model. The ability of the processes to influence development varies as a function of the *person* who is developing, the immediate and broader environmental *contexts* of that person, and the *time* in which the processes take place. This model assists in understanding the extent to which the same environments can have different effects on different people.

Implications for the Children

The stated purpose of this research was to determine the relationships among the objective dimensions of physical activity, sleep characteristics, the health indicators of body weight, and the academic parameters as measured by achievement scores and attendance records. Summarized below in Table 5.4 is an outline of the findings. The correlations seen should not be confused with causation. These findings can be helpful with not only the finest tailoring of effective interventions, but also an enhance appreciation of the multiple levels of influence on a child's developmental health. The length of wake episodes during the night sleep hours is inversely correlated with steps taken per day. Increasing the steps per hour in a measured format, possibly with a clip-on pedometer, for extended periods during the day, and appears to render a less disruptive night in the form of less length to the wake episodes. The function of wake episode frequencies throughout the night has not been studied and warrants further research. Wake episodes can be seen as a consequence of environmental noise and/or situational influences. However, what does appear to be revealed in this research is that the less wake episodes are associated with more sedentary time during the day. This again may be a picture of a sleep deprived child. Elevated percentages of sedentary or light intensity activity may be the consequence of an exhausted child. Timing of the wake cycles warrants further investigation as the energy balance is affected differently during various sleep stages. The association between more wake episodes with more moderate intensity activity during the day (either in the form of bouts or free play) is intriguing and very likely somehow implicates the energy balance equation.

The duration of sleep time at night was inversely related to moderate-vigorous intensity in the form of frequency of activity bouts. As seen by the obese child profile, this weight classification appears to be sensitive to moderate-vigorous intensity activity either in the form of free play or activity bouts. The child in the overweight class shows a significant relationship with the number of steps taken per day. In counseling and educating these children in healthy weight behaviors, it may be more effective for the overweight child to be given an exercise/physical activity regimen detailing increased steps taken in a day while the obese child may very well benefit from more moderate-vigorous activity bouts.

Attendance in the form of missed school days is seen as significantly related to more sedentary and light intensity behavior and less physical activity, either as measured in steps per day or moderate-vigorous activities. Additionally, the reading scores as rendered by the teachers is impacted negatively and significantly by the number of days missed from school. It is interesting to note that this same relationship is not seen with the mathematics scores. The reading academic achievement scores as measured by the teachers and as measured by the standardized testing are in turn significantly impacted by less physical activity as seen by steps taken in a day and moderate-vigorous activity as seen in free play or moderate-vigorous activity bouts. As the educational system notes a child, who for whatever constraint bioecologically, is bordering the truancy guidelines, as the absenteeism restrictions are being addressed, reading tutoring ought to be implemented as it is this subject that appears to bear the brunt of this limitation in schooling.

The one-size-fits all may hold true for an all-encompassing set of instructions like ‘eat healthy and get plenty of exercise’. Yet, the benefits of a modified exercise program, complemented by the additional advice related to sleep and nutrition may avail more favorable results with lifelong habits. It appears that children have different physical activity patterns and needs. By understanding an individual’s habitual energy expenditures and balances, a number of research and clinical outcomes can be exposed. Health outcomes associated with compliance to physical activity or sleep guidelines can be elucidated through the understanding and evaluation of objective data (Lyden, et al., 2010). It is essential to appreciate how to target and tailor specific interventions.

Table 5.5 Summary of Study Results/Findings

	Step per /day	VM	Vigorous activity	Bouts	Light activity	Moderate activity	Arousal length	Days missed	Sleep duration
Arousal length	Negative[*]	Negative							
Arousal frequency				Positive	Negative	Positive			
SLEEP				Negative					
OBESE profile			Sig	Sig	Sig	Sig			Sig
OVERWT profile	Sig[**]								Sig
DAYS missed	Negative	Negative		Negative	Positive	Negative			
MEAP reading				Positive					
PASS reading	Positive	Positive			Negative	Positive		Negative	
PASS Math							Negative		

[*] Negative or Positive correlation
[**] Significant relationship

Future Research

Physical activity, sleep, and academics are fundamentally pivotal in the developmental process of a child. The setting in which a child develops and the implications of his/her surroundings are direct but variable. It is imperative that we appreciate the implications as well as the barriers to maintaining consistent levels of physical activity throughout childhood. School-aged children have been impacted unfavorably by unhealthy secular trends. Perhaps increased statistical evidence of the academic value of physical activity and adequate sleep for minority and low-income children may result in increased collaboration between public health and education leaders. Additional research that highlights the financial implications and the scholastic advantages to a physically active classroom will encourage more compliance from school administrators. Efforts to bring the classroom learning outdoors to incorporate a continuum of free play, guided play, and developmental play in safe environment will enhance the learning atmosphere. Although the pretense is that children want to be active and desire the freedom to play outdoors, they are constrained by external factors such as school policy or curricula, parental rules in relation to safety and convenience, and physical environmental factors. Schools are an ideal setting in which to promote health and improve outcomes, specifically physical activity, sleep, and weight status, since such a large portion of a child's day is spent in school. Schools are in a position to offer many advantages to students. With appropriate physical activity foundations, habits can be formed. All activity does not need to be in a gymnasium. Alternatives to outdoor activity, either secondary to inclement weather or unsafe settings, merits continued creative research. Early experiences of physical activity during childhood play an important role in the maintenance of an active lifestyle that tracks into adulthood (Yang, Telama, Leino, & Viikari, 1999). High levels of physical activity at ages 9-18 years significantly predict high levels of physical activity in adulthood (Telama et al., 2005). In order to better encourage the suitability and propensity of physical activity in a child's life, it is essential to understand the bioecological factors that implicate and influence these habits. With interventional studies to evaluate activity breaks in the form of flights of stair, hallway walking, and pedometer challenges, a more accurate indication of needed activity for empirical health outcomes could be realized. Interventional studies using activity bouts as the focus of interest will assist in developing the appropriate length and frequency of intensity of recommended bouts, per weight category. Noteworthy is the fact that less than half of the elementary school-age children are meeting the physical activity guidelines and recommendations on a daily basis and as many as 40% of school-aged children experience sleep problems (Troiano, et al., 2007). Research indicates that minority and low-income children, compared to their white peers, have higher obesity prevalence rates, lower physical activity levels, less sleep duration, and poorer academic outcomes (Ogden et al., 2006).

Physical activity has been classified as obligatory (necessary for survival), voluntary (formal exercise), and spontaneous activity (related to activities of daily living) (Thorburn & Proietto, 2000). Primarily, physical activity requires a more precise definition to allow a more clear-cut determination of recommendation and guidelines as well as resulting health outcomes. It has been widely suggested that spontaneous activity, especially in children, is the main determinant of energy expenditure. Research to better determine the functional purpose of an activity bout will allow specific health sequels to be more accurately predicted. Physical activity intensity descriptions, ranges and frequencies will enable the institution of specific interventions. Additionally, interventions adapted to exclusive weight classifications, employing a bioecological framework for precision of intervention, will customize the most effective plan of care.

Although sleep is referred to as the restorative phase of the life cycle, the descriptive similarities with physical activity persist. Sleep is necessary for survival, related to activities of daily living, and often accompanied by voluntary, customary, or habitual routines. Sleep duration is determined by multiple factors, some of which may be difficult to control, whereas others may be embedded within a familial or societal context. Accurate identification of these confounders will allow and encourage more effective and precise interventions. Sleep is an essential element that warrants more consideration in the realm of health outcomes for children. It is an easily compromised commodity when time is scarce and the importance of ample sleep is often not realized. Although sleep is needed to refresh and revitalize, school schedules and early wake times discourage adequate sleep. Public policy discussions and school board meetings would benefit from additional research into the academic and fiscal benefits of manipulating school start times per age-appropriate circadian and homeostatic cycles.

Interventional trials to assess different instructional techniques per audience would enable a more population-specific dissemination of health information, particularly as it relates to the importance of sleep. Effective education and promotion of the importance of sleep requires that messages be understandable and meaningful. Continued research will encourage a user friendly application to the adjustments needed to make sleep a necessary part of a healthy life.

Studies related to the effectiveness of noise curfews in densely populated urban settings may assist in better defining the impact of such environmental variables. Current secular lifestyle modifications yield insufficient sleep durations. Additionally, research is warranted into the significance and/or function of nighttime arousals, particularly in children, as they impact health and psychosocial indicators. Shorter sleep duration is a modifiable risk factor in children, and impacts health and psychosocial outcomes, such as cognition and body weight. The longer and more-stable sleep duration is, the less likely a child is to manifest metabolic dysfunction with subsequent health implications in adulthood (Van Cauter & Knutson, 2008).

Percentile trending of body mass index has been used as the accepted and consistent method of tracking weight status and growth development in children. Additional research is needed to determine if indeed this is the most appropriate methodology as it relates to specific health outcomes. Current studies have queried the implications of measuring body adiposity, particularly as it relates to physical activity, instead of BMI. Once weight status has been determined, at what point is counsel given or treatment intervention initiated for weight loss in children? Consideration of a percentile trajectory has been offered as an appropriate starting point for weight loss in children as opposed to the absolute value of weight status. Tailoring the intervention to the weight classification has recently been addressed. Further studies with weight category specific interventions in larger populations are needed. Secondary analysis of current data from this research is planned to continue to investigate the implications of gender and specific weight classification on the study variables, as well as on the demographic correlates.

Realistic options with viable alternatives are necessary for these changeable risk factors. When considering the health of a child, all aspects of the biological health cycle and the ecological setting need to be considered. It is important to note what aspects of a child's activity pattern or sleep pattern are associated to specific health outcomes. It is still not clear whether it is necessary for children to accumulate prolonged bouts of activity for health or whether short frequent bursts are just as important. It is essential to determine whether the pattern of activity or the total activity impacts the outcome of interest. Additionally, it is imperative to ascertain the role of sleep as well with its associated frequency/length of wake episodes, and significance of arousals throughout the night.

Methodological concensus and standards in future research is mandatory. Energy expenditure and restoration is a balance. Precise and consistent measures are needed on both sides of the equation to give it accurate, profound purpose and function. With the advantages of objective monitoring and the increased use of actigraphy for the collection of sleep and activity data, the need to standardize cutpoints, epoch lengths, predition equations, and study durations is required. The same rational applies to the ability to compare academic scores across school districts. Without a standardized form of academic testing, results are not generalizable.

Future studies with larger sample sizes could compare more variables, to include access to fresh foods, sugar sweetened beverages, timing of meals and content of nutrients. The nutritional component is of course confounded by the community ambiance and economics. Healthy instructions and educational components are often set aside in the interest of convenience. Research into cultural foods, affordable entities, and preferred taste choices would advocate for an increased compliance.

By adding a longitudinal component causation could be considered. Typically, causation is viewed as being linear. In the bioecological theory, causation is circular in that there is no beginning or no end in the chain of causation. Recognition of the concept of interconnectedness is important and may require developing nurse scientists with training in environmental sciences, especially in areas that influence nursing practice. An ecological worldview would promote a more egalitarian view of life. The framework of an ecological model organizes numerous points of entry for interventions. The biological person is influenced by the setting and consequently encourages a relationship and response from the persons and community in which she/he lives. Nursing research within an ecological paradigm would reinforce the porpositions of holistic healthcare.

Given the conceptual complexities and measurement difficulties associated with physical activity and sleep in a field setting, few researchers would argue that it is difficult to detect trends and draw meaningful conclusions from the existing evidence. Future research should focus on refining these assessment methodologies to make it more sensitive to the different dimensions and contexts in different groups.

Limitations

Several study limitations need to be addressed. Enrollment was difficult in this population. With conversion to a large effect size, a reduced number of subjects were examined. The sample was homogenous and carefully selected per criteria to add to the rigor of the statistics. With additional promotion and encouragement from the school personnel, recruitment might have been more successful. The teacher burden was a reality with the current demands of the school administrations. Enrollment of parental assistance would have added a practical as well as an educational component.

Sleep and physical activity measurements were performed using actigraphy for one week, representing a typical school week. Longitudinal measurements over longer periods of time, to include holidays and seasonal variations, might reveal a more accurate predictive pattern and augment some of the associations identified in this study. Additionally, concessions for daytime or evening naps were not frequently cited in the *Exception Logs*. Although, a series of zero counts could be assumed to be sleep time when outside of the school environment, the predominantly stationary position in the school setting did not allow for such determinations. In general, the *Exception Logs* were poorly utilized. Future research might consider tape recorders or daily phone calls if finances and personnel allow.

Regarding body weight and adiposity measures, BMI is not a perfect measure, but it is an acceptable epidemiologic proxy. BMI is known to be of limited accuracy, especially in subjects with elevated lean body mass. This situation, however, was not applicable in the sample population used. BMI is routinely applied to estimate body fat, even in clinical settings, but practitioners must be aware that the measure is different for males and females with similar percent body adiposity. The gold standard is use of the dual-energy X-ray absorptiometry; but this is not realistic alternative in a free-living setting. Determination of body composition from skinfold thickness, using a prediction equation such as the Slaughter equation, may instead be a better predictor of body fatness/density in children

The use of actigraphy to measure the physical activity and sleep characteristics is not without its limitations. There are no practice standards or guidelines, universal energy cut-points, or consensus on accelerometer settings. Different epoch times might affect the prevalence rates of time spent in various levels of physical activity among children. Previous findings, using a uniaxial accelerometer, proposed that employing a shorter epoch in young children is an important issue in capturing the activity patterns in this age group (Vale, Santos, Silva, Soares-Miranda, & Mota, 2009). Agreement in standardized guidelines for actigraphy use in physical activity as well as sleep characteristics in children is essential for future studies.

Acceleration is measured and counts converted to the biological correlate of energy. The accelerometer was placed on the non-dominant wrist for the duration of the study. Some activity is admittedly missed, such as load carrying and weight lifting. It is important as well to realize that accelerometers have limitations when measuring activities with limited vertical movements, such as cycling. There is a possibility that physical activity may be overestimated when acceleration is increased by riding in a car on a bumpy road. The devices also were removed when performing water activities, which might contribute to an underestimation of physical activity.

Additionally, depending on the cut-points or activity bouts set as filters on the motion sensor, duration of intensity patterns could vary dramatically. The Freedson age-specific energy expenditure prediction equation was used to calculate cut-points. It tends to overestimate light intensity activity and underestimate vigorous activity (Lyden, Kozey, Staudenmeyer, & Freedson, 2010). The insensitivity in distinguishing between sedentary/light and moderate intensities is important given the recent focus on decreasing sedentary behaviors and accumulating short bouts of moderate activity as a means to elicit health benefits.

Also, it is important to recognize that the current recommendations to accumulate sixty minutes per day of physical activity, over and above activities of daily living, is based on epidemiological associations between self-reported physical activity and health outcomes.

Epidemiological relationships based on objective measures might result in different recommendations for activity levels.

Conclusions

Children enrolled in this study walked about with an admitted high sense of accomplishment. These eight year olds were excited to wear the wrist motion sensor. One hundred percent of the children stated that they could have worn it for a longer period of time. They were excited when others in their extended families and friends outside of the school setting noticed the device. It distinguished them as participants in an important science project as well as a recipient for a Target gift card and a contender in an iPod drawing. All of the participants, who stated it was noticed by others, claimed that this was a good thing and that made them “feel proud”. Three of the children asked if they could do ‘extra credit’ and wear it for an extended period of time. One child asked to be called again to participate in the next study. Only one child affirmed acting differently while wearing the monitor. The child attempted to excel in monitor recordings, striving to increase daily activity and be the “best”. Sixty percent of the children stated that at some point in time during the week, they totally forgot that they were wearing it. The experience of wearing the accelerometer, however, was not without some complaints and criticisms. Twenty-four percent of the sample acknowledged that the watchband was slightly irritating and itchy. This population was not accustomed to wearing wrist watches. Ultimately, however, inclusion into a research project enthused this cohort and prompted many questions and phone calls to the investigator related to health, activity, and weight, as well as logistical questions related to wearing the device. Minimal participation or involvement was seen from the home setting. Only two of the estimated fifty phone calls received on the research phone came from an adult (parent or caregiver); the remaining calls came from the inquisitive eight-year olds.

According to the physical activity intensities, this cohort spent 86% of their day in light intensity activity and less than 1% of their day in vigorous activity. Health benefits are appreciated at the higher intensities. Sixty minutes a day of moderate-vigorous activity, over and above the activities of normal living, with vigorous activity at least three times a week was simply not a reality for this cohort. Additionally, the step counts classified the boys and girls in this cohort into *low activity* and *somewhat active* categories, respectively. Physical activity opportunities were not available to this cohort. No after school sports were offered. Recess was a rare entity secondary to a dangerous environment and inclement weather. Active transport was not an option in this urban setting due to the high crime rate. Moderate-vigorous activity bouts were minimal in this cohort. Children play intermittently, sporadically and in bouts of activity. Recreation for this sample was done from the sidelines, as observers, in front of entertainment screens. Over 70% of the children reported greater than two hours of screen time per day. The physical fitness trend does not appear to be a universal phenomenon enjoyed by all neighborhoods. It is a cultural phenomenon of more affluent communities.

In addition to the unavailability of physical activity for this cohort, they were also sleep deprived as evidenced by the mean of eight hours of sleep per night. One quarter of the children did not have a consistent sleep hygiene pattern. There was no difference in hours of sleep per night according to weekdays, weekends, or gender. The ability to make-up for lost sleep on the weekends did not exist, for reasons unknown. Night time arousal time (average number of wake episodes times length of wake episodes) was confirmatory of other known research results. The significance and implications of this finding warrants further research into the significance and function of night time arousal time.

Sleep duration was confirmed in this study to be significantly related to weight. Obese children slept an average of thirty-two minutes less than normal weight children. Overweight children slept an average of forty-six minutes less than normal weight children and thirteen minutes less than the obese children. As the profile per weight status category was developed, analysis showed that the obese child had a significant and inverse correlation between light intensity activity and vigorous intensity activity. Meanwhile, the profile of the overweight child revealed a significant and inverse correlation between light intensity and steps taken per day. The uniqueness of these profiles strongly suggests that different modes of intervention may be most appropriate for different weight classes. The significance of tailoring specific physical activities for specific body weights has unique implications on the success of weight management interventions in children.

Weight status in this cohort reflected an overweight/obese sample. This group of eight year olds was a staggering 186% above the national average for obesity in this age group. Research confirms the association between sleep deprivation and weight status. The contributory nature of the high percentage of low intensity daily physical activity is also reinforced in this sample. The study protocol called for the weighing of each child prior to wearing the accelerometer. The interesting pride that the heavier children had when weighed was surprising. Only one child expressed embarrassment of the registered weight on the digital scale. All others announced their weight to their friends as if to announce an achievement or accomplishment. No statistical difference in BMI was seen in the genders.

The correlational relationships between physical activity dimensions and weight status as measured by BMI in this study were not significant. The correlational relationships between physical activity dimensions and sleep characteristics were weak, not expected, not explained in the literature, and possibly spurious.

The correlational relationships between physical activity dimensions and academic achievement and academic behavior revealed that a higher frequency of moderate-vigorous activity bouts per day were associated with the higher standardized reading scores. The passing reading students had a profile of less missed school days, lower light intensity activity, higher moderate intensity activity, and more steps taken per day. The passing mathematics students, however, had a profile of shorter wake episodes at night than those students with failing mathematics grades.

A high truancy rate was seen in these three charter schools. Missed school days ranged from a low of 9% to a high of 39% absenteeism per study child. Additionally, more school days absent was correlated with more light intensity activity and less moderate-vigorous activity. Despite the fact that this cohort had a high percentage of light intensity activity, going to school was still more activity than staying home.

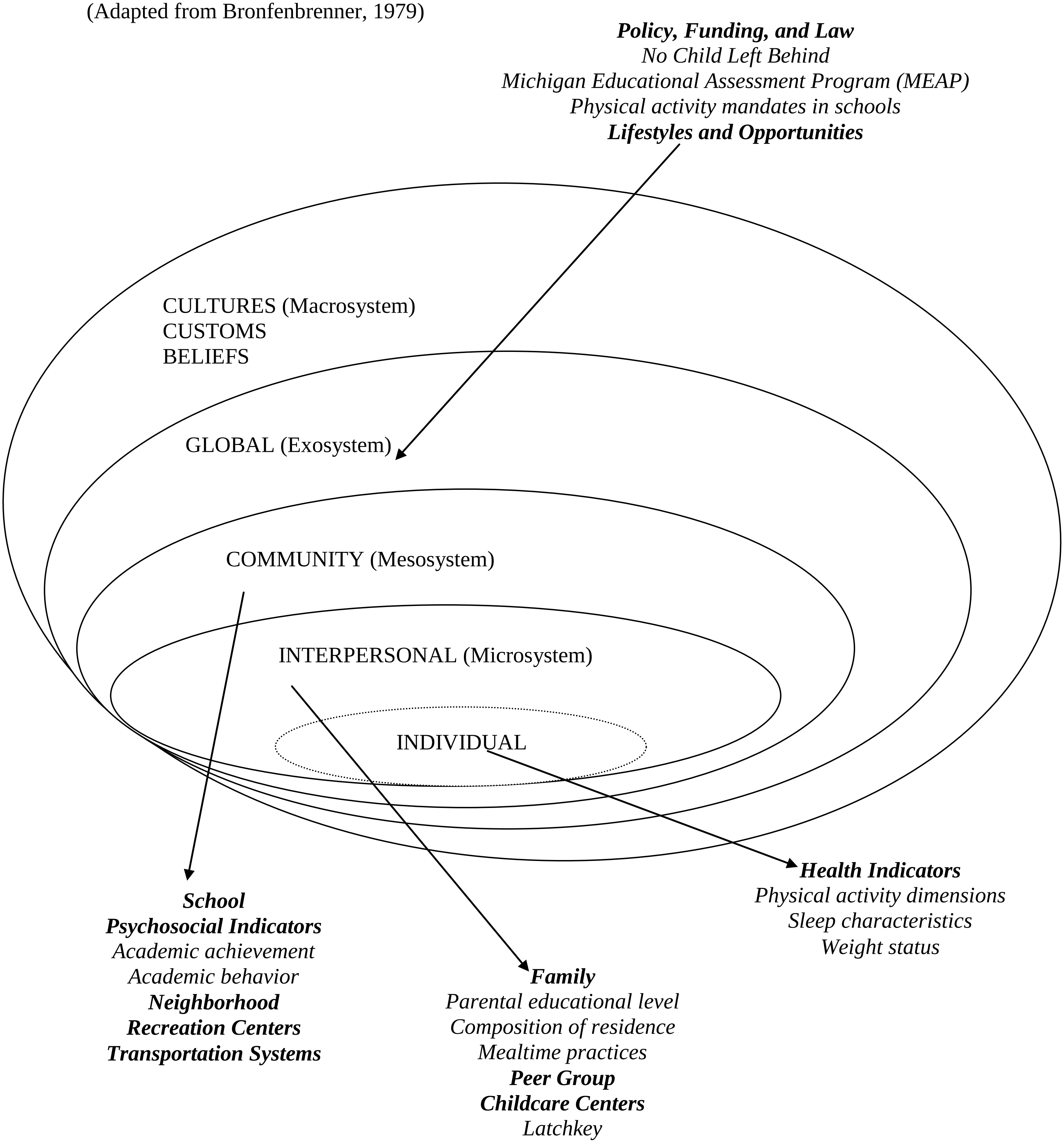
Inactivity and activity both independently exert influence over health. Accurate assessment of the dimensions of physical activity and sleep are available through the use of accelerometers. When the primary goal of research is to understand physical activity and sleep patterns, accelerometry is an excellent, unobtrusive measure. Methodology is less inconsistent recently yet it would benefit the science to establish standards of care for the sake of reliability even if the parameters need to be modified as research progresses. Uniform cut-points, similar positioning and placement, epoch ranges for distinct purposes of monitoring, duration of time needed to be worn for validity, and comparable analysis of data would add to the implications and value of the results.

The ecological representativeness of this research is not generalizable in all settings or populations. Fragmentation of the family structure served as a significant impediment to healthy lifestyle behaviors. Families infrequently ate meals together; the concept of a traditional family structure is no longer a customary occurrence.

The attainment of an energy balance in any ecological framework requires quantification of the parameters of sleep and activity as well as the ability to implement adaptations needed. The successful interchange with an environment is an art that requires awareness of the players and their roles. Nursing best practice is delegated with the charge of human betterment. This requires putting an individual in the best place and in the best condition. Interventions and treatment plans need to be as close to individual-specific as our abilities and science will allow.

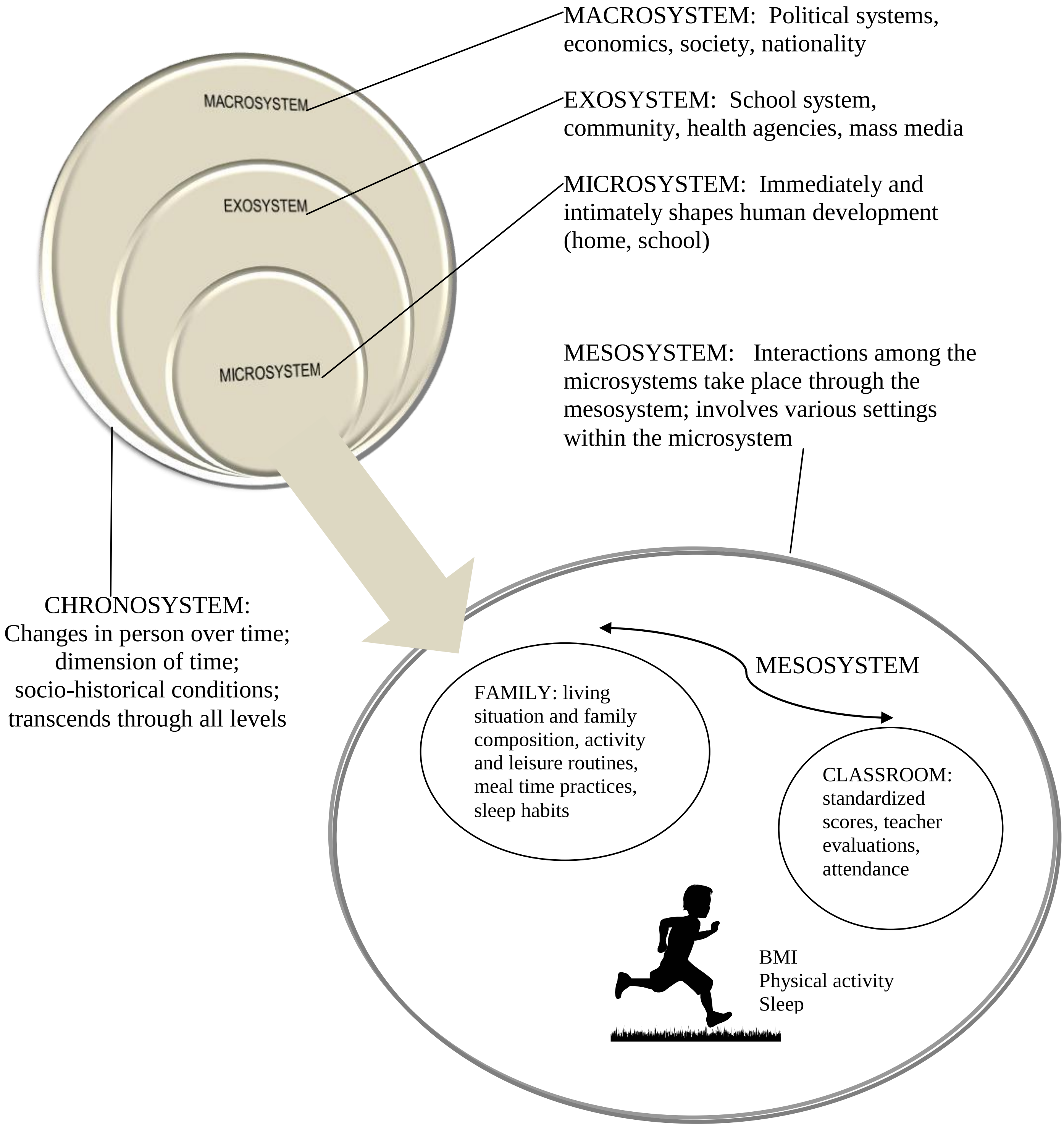
APPENDIX A ECOLOGICAL FRAMEWORK

(Adapted from Bronfenbrenner, 1979)

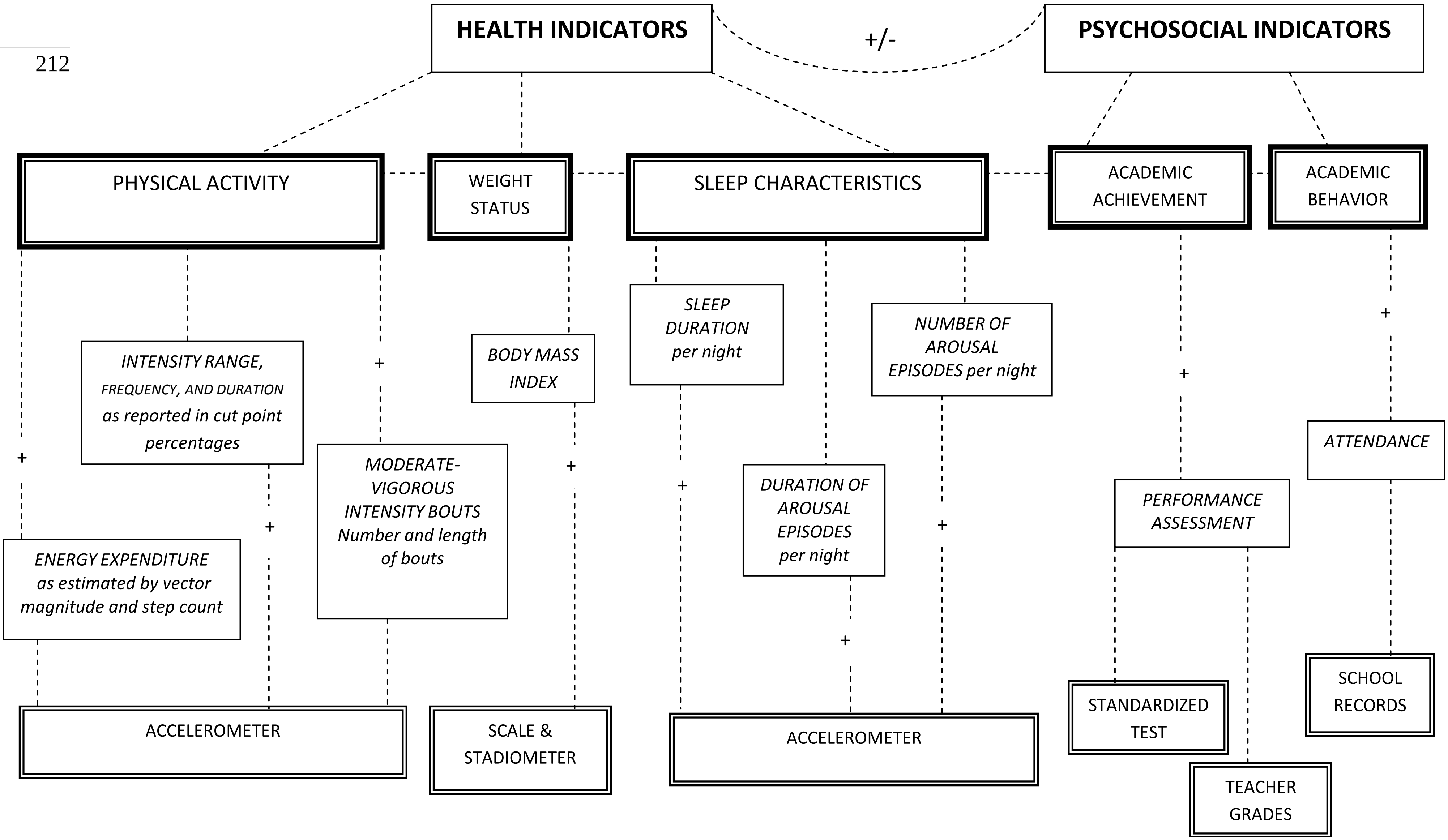


APPENDIX B. BIOECOLOGICAL FRAMEWORK

(Adapted from Bronfenbrenner, 1994)



APPENDIX C. RESEARCH FRAMEWORK



APPENDIX D - PHYSICAL ACTIVITY, ACADEMIC ACHIEVEMENT, AND ACADEMIC BEHAVIOR

Vanves, France 1950's (Shephard et al., 1984)	Never been published in English Attempt to balance intellectual and physical needs of children Increased physical activity showed superiority in psychological health & academic performance
Quebec, Canada 1970's (Shephard, 1997)	Increased (1 hour/day) physical education showed improved psychomotor abilities Increased (1 hour/day) physical education showed improved grades on standardized math test Academic performance is enhanced if curricular time is assigned to habitual physical activity Use of a specialist in physical education Assessed with average grades for French, English, natural science, and conduct : Math but not English grades improved
Australia 1978 (Dwyer, Coonan, Leitch, Hetzel, & Baghurst, 1983)	Randomized: Provided 210 min. of additional physical activity per week with no difference in academics Increased physical education showed improvement in physiologic and fitness variables 2 years later: improved trends in mathematics , reading, behavior scores (no standardized scores)
California 1990-1991 (Maynard, Coonan, Worsley, Dwyer, & Baghurst, 1987; Sallis, et al., 1999)	Randomized: Fourth and fifth graders (*n* = 759) Standardized academic testing used Use of Trained Classroom Teachers on Physical Education and Physical Education Specialists Intensive physical education program that doubled or tripled the physical education time; Increased 27-42 minutes/week physical education Students with enhanced physical education performed better than students in control group Increased physical education was not harmful on achievement test scores in elementary grades More physically active children may be better learners Increased confidence in teaching physical education may improve teaching academic subjects
Massachusetts 2000-2001 (Tremarche, Robinson, & Graham, 2007)	Fourth graders (*n* = 311) Students who received 56 or more hours of physical education per school year scored significantly higher on standardized test scores in English and language arts than did students who received 28 hours of physical education per school year; no significant differences on standardized mathematics test scores
Michigan 2006 (Coe, et al., 2006)	Sixth graders (*n* = 214) Increased physical activity by 19 minutes/day Standardized academic testing used and individual letter grades Physical activity 3 day recall and direct physical observation by physical education instructors Increases in academic performance associated with vigorous activity/ not moderate activity Decrease classroom time (55 fewer minutes of daily classroom instruction) did not translate into a lesser academic performance Physical activity ouside of the school influenced academic achievement
British Columbia 2007 (Ahamed et al., 2007)	Fourth and fifth graders (ages 9-11 yrs) (*n* = 287) Randomized: intervention group received extra 10-15 minutes/day physical activity (increased physical activity by 50 minutes/week) Physical activity self-report Standardized academic testing used Similar grades for math, reading, language arts as students receiving less physical education time No difference in math scores between girls and boys: boys were more physically active
Illinois 2007 (Castelli, Hillman, Buck, & Erwin, 2007)	Third and fifth grade (259) public school students Positively related academic achievement to aerobic capacity (fitness) BMI inversely related
Pennsylvania 2008 (Shore et al., 2008)	Sixth and seventh grade public middle school students Compared grade point averages, national standardized reading scores, and school detentions, suspensions, attendance, tardiness, fitness scores Overweight students achieved significantly lower grades (GPA and standardized), higher detention rates, worse attendance and tardiness scores

APPENDIX E - PHYSICAL ACTIVITY AND WEIGHT STATUS

(Patrick, et al., 2004)	878 adolescents aged 11 to 15 yrs Objectively monitored vigorous physical activity (uniaxial accelerometers) appeared to have an independent association with weight status for both girls and boys
(Datar, et al., 2004)	Secondary analysis of longitudinal nationally representative cohort of 10,000 children (kindergarten through fifth grade) BMI from collected survey data Physical education according to minutes per day and times per week Results predicted that increase in physical activity to 5 hours/week could decrease the prevalence of children at-risk-for-overweight by 60% and decrease the prevalence of overweight girls by 43%
(Metcalf, Voss, Hosking, Jeffery, & Wilkin, 2008)	212 boys and girls from 54 different schools between the ages of 5 – 8 years Non-intervention longitudinal study of (BMI), fatness (skin fold), metabolic status (insulin resistance, triglycerides, cholesterol/HDL ratio and blood pressure), physical activity (accelerometers) Per government physical activity guidelines (≥ 60 minutes/day) → progressive improvement seen in metabolic indicators but not in BMI or fatness
(Kamtsios & Digelidis, 2008)	775 fifth and sixth grade school children Self-report physical activity levels Anthropometric measurements per researcher Overweight and obese boys and girls only had lower physical activity scores
(McMurray, Harrell, Creighton, Wang, & Bangdiwala, 2008)	Secondary data analysis of Cardiovascular Health in Children Study (CHIC) Physical activity levels from questionnaires: pubertal development survey: BMI: skin folds Physical activity declined as children became adolescents (67% decrease in moderate and 70% decrease in vigorous activity) Decreases in moderate and vigorous physical activity changes in girls (not boys) over time correlated with increased overweight status in girls (not boys) [gender difference evident]

APPENDIX F - SLEEP, PHYSICAL ACTIVITY, AND/OR WEIGHT STATUS

(Sekine, et al., 2002)	>8000 Japanese children aged 6-7 years: Cross-sectional cohort Anthropometric data through grade school by trained school nurses: Questionnaires for parents Inverse significant association between sleeping hours and childhood obesity Risks were greater for boys than for girls Physical inactivity significantly associated with childhood obesity
(von Kries, et al., 2002)	6862 German children: 5 and 6 year olds: Cross-sectional study BMI by school health exams: Questionnaires per parents: Bioelectrical impedance Protective factors associated with overweight: sleeping ≥ 11.5 hours and regular sports activities
(Hui, Nelson, Yu, Li, & Fok, 2003)	343 Hong Kong Chinese children: aged 6–7 yrs: Case–control study Anthropometric measures by trained personnel: Interviews in the home Odds ratio for childhood overweight ↑ by birth weight and ↓ by sleeping duration
(Giugliano & Carneiro, 2004)	2500 private school children 6-10 years of age: cross-sectional study Anthropometric measures performed at lab (BMI and skin folds) Comparison of 2 groups: normal weight & overweight and obese Physical activity assessed by parental questionnaire (daily recalls of sleep, activity) 75% of daily routine distributed between hours of sleep and hours sitting: (22% obese/overweight) Number of hours of sleep may favor decrease in body fat: sleep may act positively towards maintaining healthy body composition: obese children slept significantly less than normal weight
(Agras, et al., 2004)	150 children from birth to 9.5 years Prospective exploratory study: Cohort study: Longitudinal Mother’s input and demographics: Questionnaires completed by parents Average sleep duration between 3 and 5 yrs negatively associated with overweight at 9.5 yrs of age
(Sugimori, et al., 2004)	8000+ Japanese school children: queried at age 3 and at age 6 years: Longitudinal Questionnaires completed by parents: Anthropometric measures by trained health care workers Significant factors associated with childhood overweight: short sleep duration, physical inactivity
(Reilly, et al., 2005)	8000+ British children from birth to 7 yrs: Longitudinal; prospective; cohort study Medical records, anthropometric measures, demographics Short sleep duration at 30 months predicts obesity at age 7 years
(Chaput, et al., 2006)	400+ Quebec 5-10 year school children: cross-sectional study Telephone administered questionnaires: anthropometric measures by kinesiologists Significant negative association between sleep duration, BMI, waist circumference in male children only: physical inactivity significantly associated with childhood overweight/obesity
(Eisenmann, Ekkekakis, & Holmes, 2006)	6000+ Australian children 7-15 years old: cross-sectional population: Self-reported health behaviors Anthropometric measures, waist circumference per professionals Significant association between sleep duration, BMI, and waist circumference in boys only
(Biggs & Dollman, 2007)	Revisit of Eisenmann’s findings of 2006 Included physical activity as a covariate Two groups: 9-11.9 yrs (1300 boys and girls) and 13-16 yrs (2300 boys and girls) Secondary analysis from data from the Australian Health and Fitness Survey 1985 Anthropometric variables measured: sleep duration self-reported Short sleep duration remains an independent predictor of BMI in boys after controlling for activity
(Lumeng, et al., 2007)	785 9-12 year old children: longitudinal study Parental questionnaires: anthropometric measures by trained staff Less sleep in 6^{th} grade associated with increased concurrent risk of overweight in 6^{th} grade Less sleep in 3^{rd} grade associated with overweight in 6^{th} grade
(Snell, et al., 2007)	1441 children ages 3-18 years: Longitudinal study from secondary data analysis: Child Development Supplement of the Panel Survey of Income Dynamics Time diary method completed by parents and children: Anthropometric measures performed by interviewer: Sleeping < 8hours a night was correlated with higher BMI

(Nixon, et al., 2008)	600 New Zealand children: phase 4 of a longitudinal study Parents interviewed and supplied data for sleep questionnaires: Anthropometric measures: bioelectrical impedance to assess body composition: Wechsler IQ scale: blood pressures: 24 hours actigraphy and sleep diary: Children sleeping < 9 hours were more likely to be overweight or obese and to have a greater percent of body fat Short sleep duration, as measured by actigraphy, was shown to be an independent risk factor for obesity/overweight
(Liu, et al., 2005)	335 children (cohort of pediatric affective disorders) ages 7-17 years; 3 consecutive nights of standard PSG and BMI assessments: pubertal development determined Short sleep time is associated with overweight in children and adolescents: Overweight children slept about 22 minutes less, had lower sleep efficiency, shorter REM sleep, lower REM activity and density and longer latency to the first REM period
(Touchette et al., 2008)	1400 children seen yearly from 5 months to 6 years (Canadian) BMI measured at 2.5 yrs and 6 years; sleep reported at 2.5, 3.5, 4, 5, 6 yrs. Parental questionnaires related to confounders (SES, breastfeeding, introduction to solids, activities) Persistently short sleepers during childhood (<10hr) were at significantly greater risk for developing overweight/ obesity than children who slept ≥ 11hr. Effect of short sleep duration on BMI is probably cumulative over time

APPENDIX G - SLEEP, ACADEMIC ACHIEVEMENT, AND ACADEMIC BEHAVIOR

(Kahn et al., 1989)	Survey study; questionnaires completed by parents 21% poor sleepers failed at least one year of school compared to 11% of normal sleepers
(Sadeh, Raviv, & Gruber, 2000)	Actigraphy monitoring of 140 school children (2^{nd}, 4^{th}, and 6^{th} graders) for 4-5 consecutive nights; questionnaires and daily logs completed by children and parents Strong link between daytime sleepiness and nighttime sleep patterns: possible causal link between sleep loss and learning and attention deficits
(Sadeh, et al., 2002)	135 adolescents ages 7 to 12 years Neurobehavioral evaluation based on several different tasks (motor speed, sustained attention, concentration, memory and learning span) compared to good and poor sleepers: significant correlation between measures of sleep quality and sleep fragmentation with performance decrease reflecting attention deficit and compromised executive control: effects more evident in younger students (more vulnerable to insufficient sleep)
(Steenari et al., 2003)	60 school children ages 6 to 13 years Actigraphy for 72 continuous hours: investigated link between auditory and visual working memory and sleep Lower sleep efficiency and longer sleep latency were associated with a higher percentage of incorrect responses at all levels of tasks Shorter sleep duration only affected performance at the more-demanding level of task

APPENDIX H - WEIGHT STATUS, ACADEMIC ACHIEVEMENT, AND ACADEMIC BEHAVIOR

(Sargent & Blanchflower, 1994)	Obese females perform worse at ages 7, 11, and 16 years of age than their nonobese peers; obese females at 16 yrs had lower reading test scores later in life than nonobese peers; Men and women who had been obese at age 16 years had significantly fewer years of schooling than did their nonobese peers; retrospective study
(Tershakovec, Weller, & Gallagher, 1994)	104 3rd and 4th grade black, inner-city school children Weight status determined by triceps skin fold criteria Behavior assessed by questionnaires and surveys completed by primary care takers No relationship between obesity and classroom failure
(Campos, Sigulem, Moraes, Excrivao, & Fisberg, 1996)	Children (8-13 years of age) with normal height/weight ratios had significantly better performance in IQ than those in the obese group; small sample size
(Falkner et al., 2001)	Cross-sectional study involving students (4742 males and 5201 females) in Minnesota public middle and high school Self-reported weights Questionnaires completed anonymously by students Obese adolescents girls were 1.5 times more likely to be held back a grade and 2.1 times more likely to consider themselves poor students compared to normal-weight girls. Obese adolescent boys were 1.5 times more likely to consider themselves poor students and 2.2 times more likely to expect to quit school
(Laitinen, Power, Ek, Sovio, & Jarvelin, 2002)	Longitudinal, population-based study of 9754 subjects Data gathered from national registers in Finland from birth through age 31 Obesity at age 14 years is associated with low school performance at age 16years as well as a low level of education persisting until at least age 31 years
(Crosnoe & Muller, 2004)	Social psychological approach to obesity (romantic versus athletic focused schools) Adolescents (grades 7-12) in the 85th or higher percentile of the BMI distribution had lower mean grade point averages than those in the lower 85th percent of the distribution; adolescents at risk of obesity had lower academic achievement over a one year span: reflected social world of the school
(Datar, et al., 2004)	National sample of kindergartners in the U.S. (>11,000) Overweight children had significantly lower math and reading scores that persisted through the end of first grade as compared to nonoverweight children (adiposity as a surrogate of SES)
(Huang, Goran, & Spruijt-Metz, 2006)	Asian, Latino population Surveyed (666) 11-14 yr old students from seven middle schools; anthropometric measures (BMI and bioimpedence for <u>body fat %</u>) taken by clinicians, grades self-reported and obtained from school records; physical activity self reported Adiposity was only related to the self-reported grades Moderate-to-vigorous physical activity associated with both measured and self-reported grades (self-reported & measured may be 2 unique constructs) Moderate to vigorous physical activity was associated with lower academic achievement
(Datar & Sturm, 2006)	National representative sample of children who entered kindergarten in 1998 Longitudinal study; data gathered on body mass index and school outcomes at kindergarten entry and at end of third grade Change in overweight status during the first four years of school (going from not-overweight to overweight) was significantly associated with reductions in test scores, and teacher ratings of social-behavioral outcomes and approaches to learning among girls
(Li, Dai, Jackson, & Zhang, 2008)	Children (2519) aged 8-16 years: nationally representative sample Cross-sectional survey design Secondary data analysis: Third National Health and Nutrition Examination Survey Significant negative association between cognitive function (as measured by a neuropsychological battery) and high BMI

APPENDIX I - USE OF ACCELEROMETERS TO MEASURE SLEEP AND/OR PHYSICAL ACTIVITY

(Gorely, Nevill, Morris, Stensel, & Nevill, 2009)	589 children, ages 7-11 years Multi-component school based intervention study Curriculum package (on physical activity and nutrition guidelines and goals) given to teachers for autonomous instruction (for intervention group) Accelerometers (uniaxial): five second epochs, seven days, worn during the waking hours only Intervention resulted in significant increases in physical activity: objective measures of physical activity (rigorous and sensitive test of the intervention effects without bias associated with self-reports
(Tanaka & Tanaka, 2009)	157 Japanese children, ages 4-6 years Non-interventional correlational study Children wore uniaxial (pedometer) and triaxial monitors during daytime hours for one week to determine the association between daily step counts and minutes of engagement in moderate-vigorous physical activity Daily step counts give valid information on daily physical activity for preschool-aged children: results suggest that 13,000 steps/day are required for preschool children to engage in more than 100 min of moderate-to vigorous physical activity
(Metcalf, et al., 2008)	212 boys and girls from 54 different schools between the ages of 5 – 8 years Non-intervention longitudinal study of (BMI), fatness (skin fold), metabolic status (insulin resistance, triglycerides, cholesterol/HDL ratio and blood pressure), physical activity (accelerometers) Per government physical activity guidelines (≥ 60 minutes/day) → progressive improvement seen in metabolic indicators but not in BMI or fatness Fewer than half of young boys and only one in eight girls meet the government guideline for physical activity Accelerometers (uniaxial): one minute epochs, seven day at each for four annual time points, worn around the waist, worn during the waking hours only
(Rowlands, Pilgrim, & Eston, 2008)	84 children, aged 9-11 years Non interventional study using uniaxial accelerometers during daytime hours for 4 weekdays and 2 weekend days Accelerometers were programmed to record in 2 second epochs Overall boys accumulated more activity than girls; children accumulated more activity on weekdays than on weekend days Light and moderate activity was accumulated in bouts of at least 5 minutes; more intense activity was largely accumulated sporadically Differences in activity levels among the children was due to the intensity of the most frequent bouts of activity and the frequency of the most intense bouts
(Timperio et al., 2008)	163 children, ages 8-9 years, and 334 adolescents aged 13-15 years Accelerometers (uniaxial): one minute epochs, seven days, worn around the waist on their right hip, worn during the waking hours only Examined the association between proximity of public spaces/playgrounds and physical activity in children: positive association seen only in young boys' physical activity

(Riddoch, et al., 2007)	Birth cohort, 5595 11 year old children Accelerometers (uniaxial): one minute epochs, seven day at each for four annual time points, worn around the waist over the right hip, worn during the waking hours only Greater compliance from children whose mothers had higher levels of education 40% of boys and 22% of girls met the current health related recommendations of 60 minutes of MVPA (moderate-vigorous physical activity) daily
(Patrick, et al., 2004)	878 adolescents aged 11 to 15 yrs Accelerometers (uniaxial): one minute epochs, seven days, worn around the waist, worn during the waking hours only Objectively monitored vigorous physical activity Failing to meet the 60 minutes a day of moderate to vigorous physical activity guidelines was associated with overweight status for both girls and boys

APPENDIX J - GT3XPLUS ACTIGRAPH ACCELEROMETER

(released 9/2010: upgrade of GT3X))

Transducer	Tri-axis, solid state accelerometer
Dynamic Range	+/- 3G
Dimensions	3.8 cm x 3.7 cm x 1.8 cm
Weight	27 g
Capacity	16MB or 400 Days when set to capture 3-axis activity and steps at 60 second epochs
Battery Life	20 Days (fully charged)
Communication	USB 2.0
Resolution	12-bit A/D conversion; 1.46 mG (raw data)
Sample Rate	30 Hz (static)
Parameters	Activity, Steps, Inclinometer
Calibration	Not required
Water Resistant	Splash

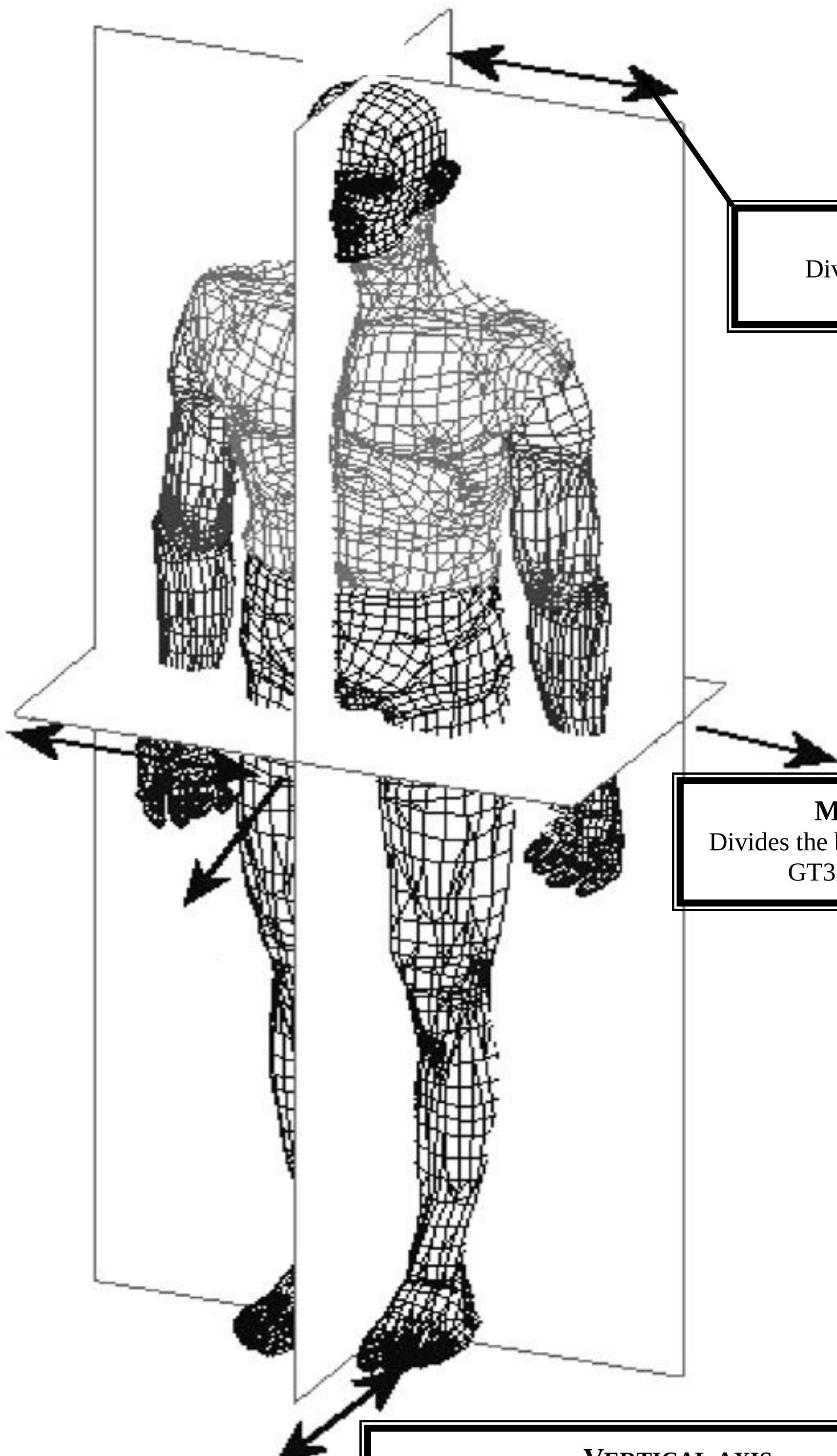
The ActiGraph GT3X activity monitor provides physical activity measurements including activity counts and vector magnitude, energy expenditure, steps taken, activity intensity levels, and MET's. It has an inclinometer to determine subject position and identify periods when the device has been removed. The GT3X can also be worn during periods of sleep to measure the amount and quality of sleep.

APPENDIX K - PLANES AND AXES ON THE HUMAN BODY

THE TRIAXIAL ACCELEROMETER

Acceleration (rate / intensity) along 3 planes:

1. ANTERIOR-POSTERIOR
2. MEDIOLATERAL
3. VERTICAL



ANTERO-POSTERIOR AXIS
Divides the body into front and back halves
GT3X Axis 2: Horizontal X-axis

MEDIOLATERAL AXIS
Divides the body into upper and lower halves
GT3X Axis 1: Vertical Y-axis

VERTICAL AXIS
Divides the body into left and right halves
GT3X Axis 3: Side to side

APPENDIX L – WSU HIC APPROVAL

WAYNE STATE UNIVERSITY

HUMAN INVESTIGATION COMMITTEE
87 East Canfield, Second Floor
Detroit, Michigan 48201
Phone: (313) 577-1628
FAX: (313) 993-7122
http://hic.wayne.edu

Association for the Accreditation of Human Research Protection Programs, Inc. Full AAHRPP Accreditation

NOTICE OF FULL BOARD APPROVAL

To: Susan Harrington
College of Nursing
301 Cohn Rm

From: Dr. Scott Millis N. Nahen for
Chairperson, Behavioral Institutional Review Board (B3)

Date: October 28, 2010

RE: HIC #: 083410B3F

Protocol Title: The Correlation of Objectively Measured Physical Activity and Sleep with BMI, Academic Achievement, and Attendance in Eight-Year-Olds

Sponsor:

Protocol #: 1008008639

Expiration Date: October 20, 2011

Risk Level / Category: 45 CFR 46.404 - Research not involving greater than minimal risk

The above-referenced protocol and items listed below (if applicable) were **APPROVED** following *Full Board Review* by the Wayne State University Institutional Review Board (B3) for the period of 10/28/2010 through 10/20/2011. This approval does not replace any departmental or other approvals that may be required.

- Brochure
- Oral Assent Script/Form
- University Preparatory Academy Parental Permission/Research Informed Consent (dated 10/1/10)
- Plymouth Educational Center School Parental Permission/Research Informed Consent (dated 10/1/10)

- Federal regulations require that all research be reviewed at least annually. You *may* receive a *"Continuation Renewal Reminder"* approximately two months prior to the expiration date; however, it is the Principal Investigator's responsibility to obtain review and continued approval ***before*** the expiration date. Data collected during a period of lapsed approval is unapproved research and can never be reported or published as research data.
- All changes or amendments to the above-referenced protocol require review and approval by the HIC **BEFORE** implementation.
- Adverse Reactions/Unexpected Events (AR/UE) must be submitted on the appropriate form within the timeframe specified in the HIC Policy (http://www.hic.wayne.edu/hicpol.html).

NOTE:

1. Upon notification of an impending regulatory site visit, hold notification, and/or external audit the HIC office must be contacted immediately.
2. Forms should be downloaded from the HIC website at **each** use.

APPENDIX M - CONFIDENTIALITY PROCEDURE

CONFIDENTIALITY PROCEDURE

A master list was generated with the student's name and identification number as the monitors were applied in the fall of 2010. The student's *Demographic Survey* and *End-of-Study Questionnaire* were identified by this same number.

Student's name	**Identification number**

The principal investigator maintained the list with only identification numbers after the enrollment process was completed. The master list was sent for safe-keeping and confidentiality to the research assistant.

Identification number	**Demographic Survey** *(check when completed)*	**End-of-Study Questionnaire** *(check when completed)*

The third grade teachers were emailed the master list by the research assistant in March 2011 and asked to fill in the student's grades, MEAP scores, and attendance record.

Student's name	**ID number**	**MEAP score**	**Grades**	**Days absent**

After completing the form, the teachers emailed the form back to the research assistant, who remained blinded to the study process and protocol. The research assistant deleted the student names from the master list and emailed the anonymous list to the principal investigator.

ID number	**MEAP score**	**Grades**	**Days absent**

APPENDIX N - ORAL ASSENT SCRIPT/FORM

I want to tell you about a research study I am doing. A research study is a way to learn more about something. I would like to find out more about the relationship between physical activity, sleep, school grades, MEAP scores, attendance, and body size in eight year olds. You are being asked to join the study because you are eight years old and will be taking the MEAP test for the first time this fall.

If you agree to join this study, you will be asked to answer some questions about your life, wear a motion sensor (looks like a bulky wrist watch) on your wrist for a week, and return at the end of the week to fill out one more paper on how the week went with the motion sensor. In addition, every day you will need to write down the time you go to bed at night, the time you get out of bed in the morning, and any time you take the motion sensor off (like when you take a shower or go swimming).

There are no known risks to wearing this motion sensor.

This study will help us learn more about the connection between physical activity, school grades, MEAP scores, school attendance, and body size in eight year old children.

You do not have to join this study. It is up to you. You can say okay now and change your mind later. All you have to do is tell us you want to stop. No one will be mad at you if you don't want to be in the study or if you join the study and change your mind later and stop.

This study was explained to your parents and they said that I could ask you if you want to be in it. You can talk this over with them before you decide, if you would like.

Before you say ***yes or no*** *to being in this study, we will answer any questions you have. If you join the study, you can ask questions at any time. Please feel free to contact Susan Harrington at 248-403-6461.*

____ ____________________

Oral Assent (children age 7-12) obtained by Date

APPENDIX O - METHODOLOGY RESEARCH FRAMEWORK

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HEALTH INDICATOR		*PHYSICAL ACTIVITY*	ENERGY EXPENDITURE as estimated by vector magnitude and step count	TRIAXIAL ACCELEROMETER
			INTENSITY RANGE, DURATION, and FREQUENCY as reported in cut point percentages	
			NUMBER AND LENGTH OF M-V INTENSITY BOUTS	
		SLEEP CHARACTERISTICS	SLEEP DURATION average per night	
			NUMBER OF WAKE EPIS0DES average per night	
			DURATION OF AROUSAL TIME average per night	
		WEIGHT	BODY MASS INDEX	SCALE AND STADIOMETER
PSYCHOSOCIAL INDICATOR	*ACADEMIC*	*ACHIEVEMENT*	PERFORMANCE ASSESSMENT	STANDARDIZED TEST and GRADES from TEACHER
		BEHAVIOR	ATTENDANCE	SCHOOL ABSENTEE RECORDS

APPENDIX P - TRAVELING MEASURING KIT

HM200P/321 - Traveling Measuring Kit

- Capacity: 350 lb
- Graduation: 0.1 lb
- Platform Size: 12.6 x 12.3 x 1.4 inches
- Includes: 214 Road Rod Portable Stadiometer, UC-321 Scale, QM2000 Measure Mate and QM214 Carrying Case

APPENDIX Q - DEMOGRAPHIC SURVEY

Demographic Survey	Student ID:							
Gender	BOY	GIRL						
Date of Birth	MONTH:	YEAR:						
Race/ Ethnicity	American Indian	Asian	African American	Hispanic / Latino	White	Native Hawaiian		
Live with both parents	YES	NO						
Highest level of parents' education	GRADE SCHOOL	HIGH SCHOOL	TRADE SCHOOL	COLLEGE / UNIVERSITY				
After school caregiver	PARENT	GRANDPARENT	RELATIVE/FRIEND					
Number of siblings	1	2	3	4	5	6	7	8
Meals eaten at home /day	1	2	3					
Meals eaten with whole family/day	YES	NO						
What do you do when you play?	RUN	PLAY BALL	RIDE A BIKE	WALK AROUND	HANG OUT / SITTING			
How often do you go outside to play?	EVERY DAY: ONLY ONCE A DAY	EVERY DAY: SEVERAL TIMES A DAY	NOT EVERY DAY					
Hours of screen time per day?	LESS THAN 2 HOURS	BETWEEN 2 AND 5 HOURS	MORE THAN 5 HOURS					
How do you usually get to and from school/day?	WALK	BUS	RIDE IN CAR	RIDE BIKE				
Do you get recess at school?	NEVER	EVERY DAY	2 OR 3 DAYS A WEEK					
Where do you sleep on most nights of the week	OWN BED / BEDROOM	SOFA/FLOOR	NOT THE SAME PLACE EVERY DAY					
Do you take pills daily	YES	NO						

APPENDIX R - END-OF STUDY QUESTIONNAIRE

End of Study Questionnaire		
Did you act any differently while wearing the motion sensor?	YES	NO
Did the motion sensor prevent you from doing anything that you normally would do?	YES	NO
Did the motion sensor bother you in any way?	YES	NO
Could you have worn the motion sensor for more days?	YES	NO
Did the motion sensor bother you more at certain times of the day?	YES	NO
Did other people notice you wearing the motion sensor?	YES	NO
Was the motion sensor difficult to wear?	YES	NO
What would have made wearing the motion sensor easier?		

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ABSTRACT

OBJECTIVE PHYSICAL ACTIVITY AND SLEEP CHARACTERISTIC MEASUREMENTS USING A TRIAXIAL ACCELEROMETER IN EIGHT YEAR OLDS

by

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August 2011

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Background: Secular trends demonstrate that young children are less active and sleep less. Inequity in an individual's energy balance is known to have poor health outcomes. Academic achievement, academic behavior, and weight status are proxy indicators for health and psychosocial outcomes in this study. Current guidelines in place for sleep and physical activity in childhood are the result of data collected in the form of self-reports. Quantification and qualification of physical activity dimensions and sleep characteristics are essential not only for the purpose of clearly establishing parameters but also for the intent of verifying optimal health outcomes and evaluating interventions related to conditions of energy balance.

Purpose: The purpose of this research was to determine the relationships amongst and between the objective dimensions of physical activity, sleep, weight status, academic achievement, and academic behavior.

Methods: This cross-sectional correlational descriptive design study monitored the physical activity and sleep duration for 24 hours per day for 7 consecutive days with triaxial accelerometers. Data was successfully gathered on 55 low socioeconomic income African American eight-year-olds. Weight status was measured and body mass index (BMI) was

calculated. Standardized scores, subjective grades from the teachers, and attendance records were obtained from the schools. A qualitative component gathered demographic information related to home life, meal habits, and play times.

Results: This sample was predominantly overweight/obese. Light intensity activity accounted for 86% of their daytime hours while vigorous activity accounted for less than 1%. Moderate-vigorous activity bouts were inversely significantly correlated with the standardized reading scores. Students with failing reading scores had significantly more time per day in light activity and less time in moderate intensity activity. This sample averaged 8 hours of sleep per night. Students with failing math scores had significantly longer mean wake episodes at night. A significant difference between hours of sleep and weight status was seen. The overweight/obese child slept, on average, less than the normal weight child.

Conclusions: Sleep is an important health indicator. Lack of sleep has academic implications. Different weight classifications may benefit from different interventional activities. Future studies should be conducted with larger and diverse samples.

AUTOBIOGRAPHICAL STATEMENT

Positive family influences of my childhood reflect the person I am today. My father was always a central figure in my life. He raised the six of us with the unwavering conviction that education was as necessary as breathing. We were taught that learning was a skill/ability that no one could ever take from us. Both my mother and father lead by their examples. My father taught at a local university after retiring from the business world. My mother attended law school after my youngest sibling entered high school. She continues to practice full-time, 30 years later. My parents told me that hopes and aspirations, as well as goals and accomplishments, were all part of life. There was nothing off-limits when it came to ambitions and education was the key that opened the door to any dream. I appreciate that it was my determination in conjunction with my beliefs that became the motivation to succeed at whatever challenge was set before me. I do not recall a time in my life when I did not dream of being a nurse. I began working in hospitals at the age of thirteen as a volunteer. Since that time, the dream has not diminished only grown. I raised five beautiful children, while continuing to work in some capacity in the nursing field, and instilled in them the love of learning. All five are college graduates. When my youngest was in high school, however, I (like my mother) went back for more education. I have been in school full-time for the past seven years and continue to work in some capacity in nursing. My experiences include critical care, nurse manager, home care, quality assurance, director of clinical trials, and care management. My hunger for being a life-long learner has immersed me into the field of nursing education and research. I know that I will be learning from my students just as they are learning from me. I intend to add to the science of nursing in the area of pediatric health. I will continue to merge my own personal experiences with science at the research table to address the obesity problem in children. My goal is to instruct and challenge students and provide them with enough information to make them thirsty for more knowledge. I hope to cultivate their inquisitiveness to advance their own research base. There is no limit to the abilities when an enthusiasm is nurtured and belief in one's self is supported.