LONGITUDINAL RELATIONSHIPS BETWEEN PHYSICAL ACTIVITY, SEDENTARY BEHAVIORS, AND OBESITY IN CHILDREN AND ADOLESCENTS

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ABSTRACT

HyunJu Park: Longitudinal Relationships between Physical Activity, Sedentary Behaviors, and Obesity in Children and Adolescents
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This secondary data analysis examined: (a) longitudinal trajectories of physical activity, sedentary behaviors, and obesity, (b) predictors of health behaviors (physical activity and sedentary behaviors) across age, (c) longitudinal relationships between obesity and health behaviors, and (d) interactions between physical activity and sedentary behaviors on obesity. The sample consisted of 3,805 subjects aged 8 to 19 years, who enrolled in the Cardiovascular Health in Children and Youth (CHIC) study from rural North Carolina. Each subject was observed a maximum 4 time points. SAS Proc Mixed (9.1.3) was used for analyses.

Physical activity decreased and obesity increased as subjects grew older. Hours of TV viewing and video games also decreased with age. A faster decrease in physical activity with age was associated with early and mid-puberty, girls, black youth, children from the highest family income group and children with obese parents. Black youth watched TV and played video games more than their white counterparts. Boys spent more time in video games than girls. While vigorous activity was negatively related to obesity, the significance disappeared after adding parental characteristics in the models. Parental obesity was a stronger predictor for child obesity than child physical activity. Video games, not TV and computer use, were positively related to obesity longitudinally. Of particular importance sedentary behaviors were not inversely related to physical activity. Significant interaction between physical

activity and sedentary behaviors were found; while more computer use strengthened the beneficial effects of physical activity on lowering obesity, subjects with more video game play did not have the beneficial effects of physical activity on lowering obesity.

This study highlighted a critical period for intervening in physical activity and obesity for young adolescents. Because physical activity and sedentary behaviors are not in the same dimension, evaluation of both health behaviors at an individual level will be needed for the assessment of risk for obesity. In particular, even though subjects are highly active, the subjects may have higher risk for obesity if the subjects spend greater time in video games. Since parental obesity is a strong predictor for obesity, parents should be factored into obesity interventions for youth.

DEDICATION

To my mom and dad whom I love with all my heart,

Soono Park and Myunghee Hahn

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

PA	Physical Activity
LPA	Low Intensity Physical Activity
MPA	Moderate Physical activity
VPA	Vigorous Physical Activity
MVPA	Moderate to Vigorous Physical Activity
BMI	Body Mass Index
SSF	Sum of Skinfold Thickness
WC	Waist Circumference

CHAPTER 1

INTRODUCTION

Cardiovascular diseases are disorders of heart and blood circulation related to atherosclerosis, coronary heart disease, stroke, dislipidemia, hypertension, Metabolic Syndrome (MS), and diabetes (Burke, 2006; Labarthe, 1998). According to the Centers for Disease Control and Prevention (CDC), heart disease and stroke contribute more than 40% of total death in the United States (US) (http://www.cdc.gov/nccdphp/publications/aag/ cvh.htm). The CDC also estimates that heart disease and stroke cost about 394 billion dollars for health care expense and loss from death and disability in the US in 2005.

Many authors have suggested that cardiovascular disease risk could be reduced with early prevention program (McMurray et al., 2002; Moreno, 2006; Reinehr, Kiess, Kapellen, & Andler, 2004). The importance of early prevention for cardiovascular risk factors is strengthened by the fact that atherosclerotic change, which is a main cause of coronary heart disease, begins very early life period (Daniels, 2001; Lenfant, 2002). Atherosclerotic change has been found at autopsy of young individuals (age range: 3 to 31 years) (Tracy, Newman, Wattigney, & Berenson, 1995). The Pathobiological Determinants of Atherosclerosis in Youth (PDAY) study also shows that fatty streaks have been found in subjects as young as 15 years of age (Zieske, Malcom, & Strong, 2002). In addition, elevated cardiovascular risk in childhood is associated with cardiovascular health outcome in later life (Juonala et al., 2006).

In particular, obesity is a strong risk factor for cardiovascular risk development. For example, de Ferranti and associates (2006) have argued that the prevalence of the MS, which is a cluster of risk factors for cardiovascular disease, increased from 1988-1994 to 1999-2000 (9.2 % to 12.7 %) is mainly due to an increase in obesity. The positive relationship between body fat and pathologic change in cardiovascular risk, such as arterial distensibility, has been found in children and adolescent populations (Whincup et al., 2005). Thus, prevention and management of obesity should be started in early life.

Basically, excessive energy intake compared to less energy expenditure can cause obesity (Aronne & Segal, 2002; Jequier, 2002). However, obesity does not have a simple cause. Inter-relationships between genetic, metabolic, environmental, and lifestyle factors result in obesity (Baur, 2002). Among the above mentioned risk factors, health-related behaviors, including physical activity, sedentary behaviors, and eating habits, are important modifiable risk factors.

Physical inactivity is a well-known risk factor for the development of obesity. It has been accepted that increased physical activity is related to decreased risk for being obese in youth (Dencker et al., 2006; Janssen, Katzmarzyk, Boyce, King, & Pickett, 2004; Kimm et al., 2005). However, the relationship between intensity of physical activity (i.e. moderate and vigorous intensity of activity) and obesity is not clear yet. Some researchers stated that moderate physical activity is negatively related to obesity (Eisenmann, Bartee, & Wang, 2002). Others argued that moderate to vigorous is beneficial to reduce obesity (Ekelund et al., 2004; Hernandez et al., 1999). Others suggested that only vigorous activity has beneficial effects (Abbott & Davies, 2004; Patric et al., 2004; Ruiz et al., 2006).

Sedentary life style, which involves low energy expenditure, is becoming a pervasive behavior in children and adolescents (Livingstone, Robson, Wallace, & McKinley, 2003). The representative sedentary behaviors, including TV viewing, playing video games, and computer use, have also been reported as risk factors for obesity in youth (Berkey et al., 2000; Hancox & Poulton, 2006; Tremblay & Willms, 2003). Still, controversial results exist according to the measurement of sedentary behaviors. A summed screen time (hours of TV viewing plus video and computer use) has been presented as a significant risk factor for obesity (Berkey et al., 2000; Utter, Neumark-Sztainer, Jeffery, & Story, 2003; Veugelers & Fitzgerald, 2005). On the other hand, when the relationships between each behavior and obesity were investigated, inconsistent results have been reported. While some studies have found a positive relationship between frequent video game play and obesity and between computer use and obesity (Crooks, 2000; Tremblay & Willms, 2003), others have reported that digital game play did not have significant effects on obesity (Giammattei, Blix, Marshak, Wollitzer, & Pettitt, 2003; Kautiainen, Koivusilta, Lintonen, Virtanen, & Rimpela, 2005; McMurray et al., 2000). In addition, computer use did not show a significant effect on obesity (Giammattei et al., 2003; Hernandez et al., 1999).

Factors related to physical activity and sedentary behaviors have been examined in many studies. Gender, race, age, parental socioeconomic status (SES) and parental activity have been most frequently investigated as predictor (Van Der Horst, Paw, Twisk, & Van Mechelen, 2007). However, not many studies are longitudinal. Thus, how the relationships between predictors and health behaviors change as children grow needs to be examined.

The body of research on inter-relationships between physical activity and sedentary behaviors in childhood and adolescence does not provide consistent results. According to previous investigations, while some researchers argue that sedentary behaviors are inversely related to physical activity (DuRant, Baranowski, Johnson, & Thompson, 1994; Katzmarzyk, Malina, Song, & Bouchard, 1998; Marshall, Biddle, Gorely, Cameron, & Murdey, 2004; Pate et al., 1997; Strauss, Rodzilsky, Burack, & Colin, 2001; Vilhjalmsson & Thorlindsson, 1998), others claim that active and sedentary behaviors are not associated (Brodersen, Steptoe, Williamson, & Wardle, 2005; Grund, Krause, Siewers, Rieckert, & Muller, 2001; Parsons, Power, & Manor, 2005; Utter et al., 2003; Wolf et al., 1993). To further complicate the issue, some studies have found a positive relationship between computer use and physical activity (Koezuka et al., 2006; Santos, Gomes, & Mota, 2005; Utter et al., 2003). Thus, sedentary behaviors seem to have different contexts. The inter-relationship between physical activity and each sedentary behavior needs to be investigated.

One of the important underlying factors for understanding obesity is knowledge of eating behaviors. Some studies have found significant relationships between sweetened drinks and fast foods, and obesity (Murray, Frankowski, & Taras, 2005; Nicklas, Yang, Baranowski, Zakeri, & Berenson, 2003). The Bogalusa Heart Study has also shown that sweetened beverages, snacks, and low quality foods have positive relationships to obesity in young adolescents (Nicklas et al., 2003). On the other hand, many studies have failed to find a significant relationship between obesity and unhealthy eating behaviors, including low intakes of fruits and vegetables, and high intakes of soft drinks, fast foods, and fat (Field, Gillman, Rosner, Rockett, & Colditz, 2003; Janssen et al., 2005; Maffeis et al., 2000; Willett, 2002). However, eating behaviors cannot be excluded in obesity research, because energy imbalance due to excessive energy intake can cause obesity.

Parental influence is one of the strongest risk factors for the development of child obesity. Maffeis et al. (1998) have shown that only parental obesity has significant effects on child obesity, when parental obesity and physical activity of child are included in the same model. Golan and Crow (2004) have suggested that parents play an important role in childhood obesity, in that they provide an environmental context for a child. Parental obesity, activity, and SES are representative parental variables. Zeller and Daniels (2004) have stated that parental obesity is an important risk factor for childhood obesity, which may be due to sharing genetic and environmental factors. Positive association between parental and child activities have also been reported (Bogaert, Steinbeck, Baur, Brock, & Bermingham, 2003; Gilmer et al., 2003; Troiano & Flegal, 1998). In addition, parental SES, measured by family income and parental education, has been presented as a significant factor for child obesity (Goodman, Huang, Wade, & Kahn, 2003; Langnase, Mast, & Muller, 2002). In spite of the strong relationship to child obesity, not many studies have included parental influence in obesity research in youth.

Race and gender are potential moderating variables for obesity. Higher prevalence of obesity in black than in white youth has been reported (Haas et al., 2003; Ogden et al., 2006). The fact that black adolescents are less active and eat more unhealthy food than white counterparts may be part of the reason for the differences in obesity (Andersen, Crespo, Bartlett, Cheskin, & Pratt, 1998; Neumark-Sztainer, Story, Hannan, & Croll, 2002). Gender differences are also clear in physical activity. Girls are less active and more sedentary than boys (Bradley, McMurray, Harrell, & Deng, 2000; Caspersen, Pereira, & Curran, 2000; Ruiz et al., 2006; Tammelin, Laitinen, & Nayha, 2004). In addition, different determinants of obesity by gender have been found. While sedentary behaviors are more closely related to obesity in girls (Crespo et al., 2001), physical activity is more highly associated with obesity in boys (McMurray et al., 2000). However, not all studies have included these possible moderating variables in their analysis models.

Age has been presented as another correlate to physical activity, sedentary behaviors, eating behaviors and obesity. Physical activity decreased with an increase of age (Brodersen, Steptoe, Boniface, & Wardle, 2007; Gordon-Larsen, Nelson, & Popkin, 2004; Nelson, Neumark-Stzainer, Hannan, Sirard, & Story, 2006). While a group of researchers reported that sedentary behaviors (summed hours of TV, video, and computer use) increased with age in British adolescents (Brodersen et al., 2007), others presented a decreasing trend in time spent in TV and video games with age (Gordon-Larsen, McMurray, & Popkin, 1999; Nelson & Gordon-Larsen, 2006; Villard, Ryden, Ohrvik, & Stahle, 2007). Age also influences the relationship between activity and obesity. Marshall et al. (2004) reported that harmful effects of sedentary behaviors on obesity were greater in young children compared to adolescents. In addition to the relationship to activity, age also relates to eating behavior. Older children have shown increased fast food intake and increased percentage of energy from fat (Cullen et al., 2004; Schmidt et al., 2005).

To date, few studies have included pubertal status in obesity research. However, distinctive changes in body fat can be found during puberty. Boys show a slight increase in fat accumulation in early puberty and followed by a decrease during adolescence, which seems to be the result of increased muscle development (Johnson, Gerstein, Evans, & Woodward-Lopez, 2006). For girls, fat accumulation increases steadily through puberty (Johnson et al., 2006). Hence, pubertal development needs to be included in obesity research in child and adolescent populations.

In terms of obesity measurement, previous population-based obesity studies in children and adolescents have frequently used BMI and skinfold thickness as an obesity index. Not many studies have included waist circumference in children and adolescents. Considering that central adiposity shows a close relationship to cardiovascular disease (Cruz et al., 2005; Haslam & James, 2005), assessment of obesity including abdominal obesity index was helpful to broaden our understanding of obesity.

In summary, while increased physical activity and decreased sedentary behaviors have showed beneficial effects on obesity, not many studies have included important contributing factors (i.e., gender, race, age, puberty, eating behavior, and parental influence) in analyses. Thus, when underlying factors for obesity are considered, the extent of obesity that can be explained by physical activity or sedentary behaviors needs to be investigated. In addition, it is not clear how the intensity level of activities would have beneficial effects on weight status, which has important implications for developing intervention programs for obesity. Longitudinal relationships between predictors and health behaviors (physical activity and sedentary behaviors) are another topic to be investigated. More importantly, if physical activity and sedentary behaviors are not related, which mean those behaviors are not in the same continuum of activity, interactions between physical activity and sedentary behaviors on obesity should be examined. That is, studies that examine how physical activity influences obesity in different levels of sedentary behaviors are needed. Investigation of comprehensive longitudinal relationships between risk factors (physical activity and sedentary behaviors) and obesity will help us understand obesity and produce developmentally suitable intervention programs for obesity.

Purposes of the Study

The purposes of this secondary analysis of a longitudinal study were (a) to examine trajectories of physical activity, sedentary behaviors and obesity throughout maturation (age); (b) to explore how child characteristics and parental characteristics influence physical activity and sedentary behaviors across age; (c) to identify the extent of obesity explained by physical activity and sedentary behaviors across age; and (d) to examine whether there is an interaction between physical activity and sedentary behaviors and obesity across age in elementary to high school students from North Carolina. Child characteristics (puberty, gender, and race), child dietary behavior (intake of sweet drinks), parental characteristics (physical activity, obesity, and SES) were included in analyses.

Significance of the Study

One of strengths of this study can be characterized by multiple measurements. Multiple measures were used to understand diverse dimensions of health behaviors and obesity. That is, physical activity was represented by low, moderate, vigorous, and total activity scores, which made it possible to compare across activities with different intensity of physical activity. Sedentary behaviors were also investigated using hours of TV, video games, and computer use, respectively. In addition, obesity was indicated as using BMI, BMI z score, skinfold thickness, and waist circumference.

More importantly, this is a longitudinal descriptive study. Since child and adolescents are in the period of developing health behaviors, how trajectories of physical activity and sedentary behaviors change as subjects grow older will help to understand the developmental process of health behaviors. In addition, longitudinal influences of child and parental variables on health behaviors as well as longitudinal relationships between health behaviors and obesity across age will potentially provide directions for developmentally suitable interventions.

In addition, this comprehensive study investigates inter-relationships between different health behaviors and obesity, including the relationships between physical activity and sedentary behaviors, as well as interaction effects between physical activity and sedentary behaviors on obesity. In particular, this is the first study to investigate interactions between physical activity and sedentary behaviors on obesity. Therefore, the current study will add knowledge about complicated relationships between obesity and obesity related health risk behaviors and provide some implications for future interventions for obesity.

Conceptual Framework

The conceptual framework for this study was based on the developmental science perspective (see Figure 1.1). According to Magnusson and Cairns (1996), developmental science, which emerged about two decades ago, originated from developmental principles related to biology, social behaviors, and their interactions. According to this perspective, an individual functions holistically through complex reciprocal interactions with many systems, which are themselves dynamic and complex processes. Furthermore, development is viewed as a continuing process throughout life.

Miles and Holditch-Davis (2003) stated that this holistic, developmental, and system-oriented perspective fits with the holistic views of nursing and is an important perspective for health-related studies of children. They define health as “the state in which children show optimal physiological, physical, cognitive, and psychological development (p. 11).” In this study, the focus was broadly focused on cardiovascular health and, more specifically, on obesity. A major paradigm of developmental science is system theory, adapted from

Bertalanffy (1962). System theory emphasizes the dynamic inter-relationships among systems encompassing children (Magnusson & Cairns, 1996; Miles & Holditch-Davis, 2003). Ecological system theory, put forth by Bronfenbrenner (1989), pointed out the importance of nested ecologies in which the child develops, such as the community, school, peer group, and family. Too, the socio-cultural context including ethnicity and gender are important influences on development.

Another major paradigm of this perspective is a holism which emphasizes that individuals function as a totality that is influenced by internal and external systems (Magnusson, 2000). Of importance for this study was the principle that developmental processes of human beings are influenced through interactions between within-subject factors such as the behavioral and physiological systems.

The last paradigm is that human functioning is a developmental process that occurs over time throughout a lifetime (Carins, Costello, & Elder, 1996; Hodges, 2003). Thus, longitudinal designs are critical to the understanding of developmental processes and outcomes. In addition, key life transitions such as puberty as well as biological age are important roles in human development.

In this study, ecological systems theory, including the socio-cultural context, was used to identify variables that influence physical activity, sedentary behaviors and obesity. Parental characteristics, which have been found to have an influence on physical activity, sedentary behaviors and obesity, were included in analysis. Parents are an important system to consider as they share with children genetic background and share the same environment (Hodges, 2003). Parents also serve as role models. Parental characteristics included in the study were parental SES, obesity, and activity. Thus, inter-generational relationships of health behavior and obesity between parent and child were examined.

School is another important socio-cultural context for youth. Although the current study did not include a specific school level variable (i.e. number of PE classes), all analyses were done after adjusting for similarities of students in the same school district (intra-school district correlation) under the assumption that characteristics of each school in the same district (i.e. PE policy) may explain some of variance in obesity and health behaviors of students in the same district. Adjusting for school district correlation, instead of school, was due to difficulty in adjusting intra-school correlations when subjects had 2 different schools during repeated measurements due to progression (i.e. elementary to middle, or middle to high school).

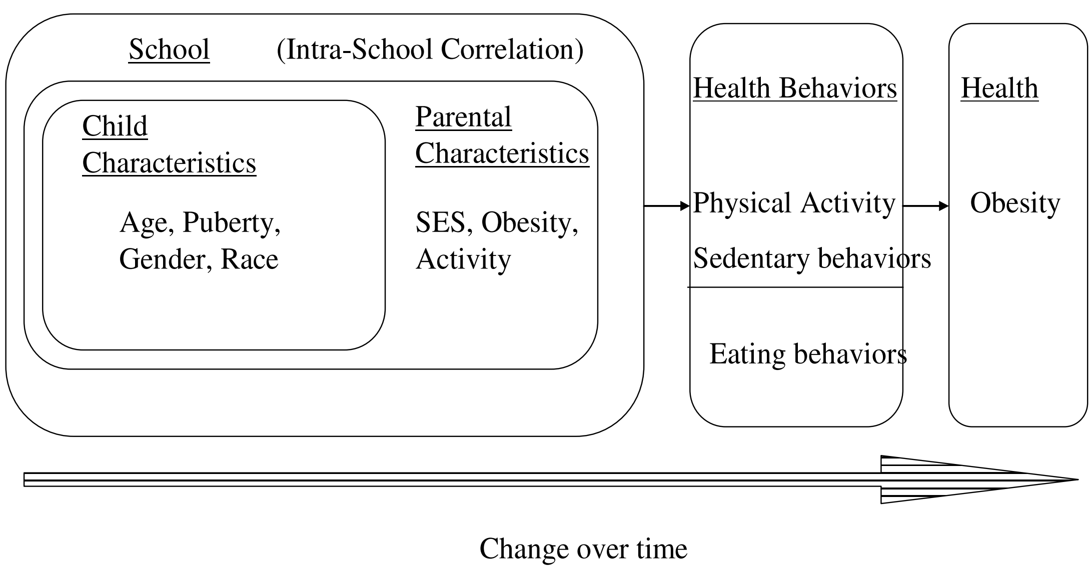
Race was included in the model as an important socio-cultural factor. Race has been found to have an influence on health behaviors such as physical activity, sedentary behavior, and obesity.

Since health behaviors and health outcomes evolve and change over time, this study used a longitudinal design to examine change over time (growth curve). Three or four data points over the period of adolescence were included. Growth curves of health behaviors (i.e., physical activity and sedentary behaviors) and health outcome (obesity) by age as well as changes by puberty (transitional period) were examined.

An important aspect of longitudinal design with adolescents is puberty, since children experience pubertal changes at different ages. Thus, puberty was considered in analysis. Furthermore, gender was included in the model as it interacts with puberty (with females entering puberty earlier than males). In addition, gender has an important socio-cultural influence in health behaviors, particularly physical activity and sedentary behavior.

Finally, based on the principle of holism, interactions between behavioral and physiological systems were investigated. In addition, it is important in developmental studies to measure phenomena using multiple indicators (Magnusson, 2000). Thus, multiple indicators were used to evaluate diverse aspects of behavioral and physiological systems. For instance, BMI, BMI z score, sum of skinfold thickness, and waist circumference, which represent different aspects of obesity, were included as indicators of obesity. Using different measures of obesity and different health behaviors provided more information of change in obesity and health behaviors throughout maturation.

Figure 1.1 Conceptual Model



Research Questions

Each research question was examined using multiple indicators: (a) obesity of children and adolescent (BMI, BMI z, SSF, and waist circumference); (b) physical activity (total activity, low, moderate, and vigorous physical activity scores); and (c) sedentary behaviors (hours of TV viewing, video game play, and computer use per week). A set of parental characteristics were family income and parental education, activity and obesity of mothers or fathers).

1. Trajectories of physical activity, sedentary behaviors, and obesity by age:

    1a) What are the trajectories of physical activity by age?

    1b) What are the trajectories of sedentary behaviors by age?

    1c) What are the trajectories of obesity by age?

2. Longitudinal relationship between physical activity and predictors:

    Do puberty, gender, race, and parental characteristics (family income and parental education, activity, and BMI risk) influence physical activity across age (as subjects grew older)?

3. Longitudinal relationship between sedentary behaviors and predictors:

    Do puberty, gender, race, and parental characteristics influence sedentary behaviors across age (as subjects grew older)?

4. Relationship between physical activity and sedentary behaviors:

    Are sedentary scores inversely related to moderate, vigorous, or total PA scores across age, when puberty, gender, race, and parental characteristics are controlled in the model?

5. Relationship between physical activity (total, moderate or vigorous physical activity) and obesity:

To what extent is child obesity predicted by moderate, vigorous, or total physical activity across age, when puberty, gender, race, sweet drink intake, and parental characteristics are controlled in the model?

6. Relationship between sedentary behaviors and obesity:

To what extent is child obesity predicted by sedentary behaviors across age, when puberty, gender, race, sweet drink intake, and parental characteristics are controlled in the model?

7. Interaction between physical activity, sedentary behavior, and obesity:

Is there an interaction between physical activity and sedentary behavior and obesity across age when puberty, gender, race, parental characteristics are controlled in the model?

CHAPTER 2

REVIEW OF THE LITERATURE

This review of the literature focuses on childhood and adolescent obesity; physical activity; sedentary behaviors; the relationship between physical activity, sedentary behaviors, and obesity; and other correlates for obesity in childhood. The review includes issues related to measurement, developmental trends, and predictors particularly of physical activity and sedentary behaviors.

Childhood and Adolescent Obesity

Obesity is defined as excessive body fat that results when intake and consumption of energy are not balanced (Aronne & Segal, 2002; 2005; Jequier, 2002; Speiser et al., 2005). Body fat, or adiposity, is composed of subcutaneous and internal fat tissue (Heymsfield et al., 2004). Although obesity of subjects should be logically determined by the amount of accumulated body fat, researchers and clinicians have frequently used body mass index (BMI) as obesity estimates because of low cost and simplicity of measurement as compare to measures of adiposity (Speiser et al., 2005). However, BMI assesses overweight, not obesity. According to the Center for Disease Control and Prevention (CDC), childhood obesity is categorized as 'at risk for overweight' when BMI of children is between 85^{th} and 95^{th} BMI percentile for gender and age (i.e., $\geq 85^{th}$ and $<95^{th}$), and 'overweight' when BMI is equal to or greater than 95^{th} BMI percentile for gender and age (http://www.cdc.gov/

nccdphp/dnpa/growthcharts/training/modules/module3/text/page5f.htm).

Obesity is rapidly increasing in children and adolescents. Researchers reported that childhood obesity (at risk for overweight or overweight) doubled over the last three decades in the United States (US) (Deckelbaum & Williams, 2001). The increasing trend of obesity in youth can easily be found in nationally representative sample data (i.e., the National Health and Nutrition Examination Surveys, NHANES). The NHANES data shows that the prevalence of overweight (equal to or greater than 95^{th} age- and gender- specific BMI percentile) has more than tripled during the last three decades (Table 2.1) (Jolliffe, 2004; Ogden et al., 2006). Therefore, statistics indicate that obesity is a growing problem in youth.

Table 2.1

Prevalence of Overweight in US Children and Adolescents from NHANES data unit (%)

	Age	At Risk for Overweight ($\geq 85^{th}$, $<95^{th}$)	Overweight ($\geq 95^{th}$)	Either at risk for Overweight or Overweight($\geq 85^{th}$)
NHANES I 1971-1974	2-19	10.2	5.1	15.3
NHANES II 1976-1980	2-19	9.2	5.5	14.7
NHANES III 1988-1994	2-19	13.1	10	23.1
NHANES 1999-2000	6-11	14.7	15.1	29.8
	12-19	15.2	14.8	30.0
NHANES 2001-2002	6-11	15.9	16.3	32.2
	12-19	14.4	16.7	31.1
NHANES 2003-2004	6-11	18.4	18.8	37.2
	12-19	16.9	17.4	34.3

Adapted from "Extent of overweight among US children and adolescents from 1971 to 2000," by D. Jolliffee (2004), International Journal of Obesity Related Metabolic Disorder, 28, 4-9 and "Prevalence of overweight and obesity in the United States, 1999-2004," by C. L. Ogden, M. D. Carroll, L. R. Curtin, M. A. McDowell, C. J. Tabak, and K. M. Flegal (2006), JAMA, 295, 1549-1555

In addition, childhood and adolescent obesity is a serious problem in terms of its psychological and physical consequences: negative effects on self-esteem, stigmatization by their friends, depression, orthopedic problems, eating disorders, hepatic complications, obstructive sleep apnea, hypertension, diabetes mellitus (DM), dyslipidemia, and metabolic syndrome (Baur, 2002; Burke, 2006; Daniels et al., 2005; Haslam & James, 2005; Schwartz & Puhl, 2003). Thus, more studies regarding prevention and treatment of obesity in children and adolescents are required.

Measurement of Obesity

The accurate measurement of obesity is critical to assess the status of obesity in each subject and to evaluate the effects of obesity intervention programs (Field et al., 2003). Frequently used methods for obesity measurement can be divided into relatively direct ways and indirect methods (surrogates of body fat). The former can actually measure the amount of adiposity. These methods include doubly labeled water (DLW), dual-energy X-ray absorptiometry (DXA), computerized tomography (CT), and underwater weighing (hydrodensitometry). However, these expensive methods can not be easily applied in population level studies. For instance, when CT was used for fat measure, 22 subjects were included (Orphanidou, McCargar, Birmingham, Mathieson, & Goldner, 1994); 121 individuals were measured body fat by DLW (Rennie et al., 2005); and 328 subjects were measured by DXA scan (Sardinha, Going, Teixeira, & Lohman, 1999). Instead, surrogates of body fat, including body weight, BMI, waist circumference, and skinfold thickness, have been used as alternatives for population studies, i.e., 2109 subjects in the study of Harrell et al. (1999) and 1294 subjects in the study of Ekelund et al. (2004).

Surrogates of body fat measures do not assess adiposity directly but estimate it indirectly. Each indicator measures different aspects of obesity. Thus, studies including a variety of surrogate measures will be helpful for more comprehensive evaluation and understanding of obesity.

Below is a brief description of surrogates of body fat indicator, including BMI, BMI z score, skinfold thickness, and waist circumference.

BMI as a measure of obesity.

Body Mass Index (BMI) is calculated as weight in kilograms divided by squared height in meters. While BMI is not a direct measure of adiposity, it has been frequently used as an indicator for obesity because of its convenience and a high correlation to mortality and obesity related disease, such as hypertension, Type 2 Diabetes, and cardiovascular disease risk in adult populations (Aronne & Segal, 2002). In addition, researchers have concluded that childhood BMI predicts cardiovascular disease morbidity in later life (Kiess et al., 2001). Therefore, BMI is a useful index for obesity.

However, BMI may not be a good index for fat mass. When BMI was compared to body fat index from DLW in adult Indonesians and Dutch Caucasians, Indonesians showed higher body fat index than Dutch Caucasians with the same BMI (Gurrici, Hartriyanti, Hautvast, & Deurenberg, 1998). When analyzing body composition indexes from hydrodensitometry, an elevation of BMI during adolescence showed higher correlation to lean mass than fat mass in 387 white adolescents aged 8 to 19 years (Maynard et al., 2001). Hence, researchers concluded that BMI does not differentiate between lean and fat mass, so muscular subjects can be mistakenly identified as obese (Aronne & Segal, 2002). Likewise, reduced BMI may not necessarily mean loss of fat because about a quarter of weight lost is from lean tissue (Prentice & Jebb, 2001). Thus, studies including supplemental measures for adiposity as well as BMI will be useful as they will allow us to assess obesity more accurately.

BMI percentile and BMI z score as a measure of obesity.

Growth is a distinctive characteristic of children and adolescents. Unlike adults, percentile values from the same age and gender groups provide more appropriate information for youth population. BMI growth charts provide a distribution of BMI change by age and gender in the reference population of those 2 to 20 years of age (http://www.cdc.gov/ nchs/about/major/nhanes/growthcharts /background.htm). Age- and gender- specific BMI percentiles indicate where the BMI of a subject is located in percentile rank of the reference populations (http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/ GrowthchartFAQs.htm). For instance, a girl aged 10 years whose BMI is at the 50^{th} percentile indicates that the BMI of the girl is at the median for 10-year-old girls in the reference population.

BMI z score is a standardized value for BMI, which shows how far an individual value is located from a mean or a median value of a reference population. In other words, BMI z score of 1 or 2 means that the BMI of an individual is one or two standard deviations above the mean or the median value of the age and gender specific reference value. According to the CDC, BMI z score and percentile are the same and interchangeable (http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/GrowthchartFAQs.htm).

Because BMI z score was developed from BMI, it may have the same weakness as BMI. However, when used to compare between repeated measures for 2 or more time points, it may have strength for the youth population in that age- and gender- specific BMI z score may distinguish growth from being obese (Thompson et al., 2004). For example, no change of BMI z score with an increase of BMI in children during a certain amount of time means that the child has likely gained weight by normal growth. In this vein, changes in BMI z score were the best indicator for longitudinal fat changes compared with BMI, weight, and standardized weight (Hunt, Ford, Sabin, Crowne, & Shield, 2007). The authors suggested that decrease in BMI z score of 0.5 over 0-6 months or 0.6 over 6-12 months reflected significant body fat change in the sample of 92 obese adolescents aged 6 to 18 years.

However, some researchers argued that BMI z score is not appropriate to use in longitudinal studies (Berkey & Colditz, 2007) because BMI z score is calculated from cross-sectional samples (Ogden et al., 2002). Since not many studies have been used BMI z score in longitudinal study, including BMI z score and the actual BMI value in a longitudinal study may broaden our understanding obesity in child and adolescent populations.

Sum of skinfold thickness (SSF) as a measure of obesity.

Skinfold thickness is an index of subcutaneous body fat. It is a measure of thickness of a double layer of skin and can be measured at several body sites (Speiser et al., 2005). It is a more direct measure for body fat than BMI (Sherry & Dietz, 2004). Sum of triceps and subscapular thickness shows an inverse relationship to all-cause mortality in adults (Zhu, Heo, Plankey, Faith, & Allison, 2003). Positive relationship between skinfold thickness and cardiovascular risks including blood pressure and lipid levels has been reported in youth (Dwyer, 1994; Williams et al., 1992). Therefore, skinfold thickness is a useful measure for fatness.

Empirical evidence has shown that skinfold thickness is better than other surrogate indicators in estimating fat mass. When compared to fat index measured by DLW in an adult population, a combined multiple site measure of skinfold thickness (sensitivity: 73.7%, specificity: 84.9%, and positive predictive value: 71.8%) was better for predicting fat free mass than BMI (sensitivity: 47.7%, specificity: 86.3%, and positive predictive value: 67.7%) (Piers, Soares, Frandsen, & O'Dea, 2000). When computerized tomography was used as a gold standard for body fatness among adults, skinfold thickness was even better in predicting subcutaneous body fat than the fat index measured by ultrasound (3-site skinfold thickness and CT: r=0.73, p=0.0001 vs. ultrasound and CT: r=0.54, p=0.009) (Orphanidou et al., 1994). Triceps skinfold thickness was reported as the best indicator for measuring fatness among BMI, triceps skinfold thickness, and upper arm girth, when percentage of body fat from DXA scan was used as a criterion in a adolescent population (Sardinha et al., 1999). That is, receiver operating characteristic analysis (ROC) shows that the area under the curves (AUCs: close to 1.0 is better) of triceps skinfold thickness ranged 0.94 to 0.96 for girls and 0.86 to 0.98 for boys. The AUCS of BMI were 0.89 to 0.95 for girls and 0.61 to 0.97 for boys. Measures of body fat developed using equations of Slaughter that included triceps and subscapular skinfolds were highly correlated with percent body fat from DXA (Pearson r=.92) (Steinberger et al., 2005). Therefore, previous studies have documented the accurateness of skinfold thickness as a body fat measure.

However, skinfold thickness measures have limitations. First, low inter-rater reliability is a problem (Sherry & Dietz, 2004; Speiser et al., 2005). Low test-retest reliability is another issue (Sherry & Dietz, 2004; Speiser et al., 2005). Last, it has been reported that in the case of fat subjects, skinfold thickness is difficult to measure and the value may be less reliable (Sherry & Dietz, 2004; Speiser et al., 2005). Thus, while skinfold thickness provides an assessment of adiposity, the difficulty in obtaining consistent, reliable measurement makes BMI a more reliable way to assess obesity even though it does not actually measure body fat.

Waist circumference as a measure of Obesity.

Recently, waist circumference (WC) has been a more popular research focus of obesity due to a close association with the Metabolic Syndrome (MS). The MS is a common cluster of risk factors for cardiovascular disease and type 2 diabetes (Burke, 2006; Morrison et al., 2005). WC is an indicator of central adiposity (Bray & Bellanger, 2006; Speiser et al., 2005). The comparison to a central obesity index measured by a CT showed accurateness of WC in terms of central obesity in adolescents. That is, when BMI and WC were included as predictor variables in the same model, WC significantly predicted central obesity measured with a CT ($p < .01$) but BMI was not significant (Lee, Bacha, Gungor, & Arslanian, 2006).

Similar to other surrogates of body fat, WC showed a positive relationship to cardiovascular risk, such as insulin sensitivity, hypertension, dyslipidemia, and the metabolic syndrome in adult and adolescent populations (Janssen, Katzmarzyk, & Ross, 2004; Lee et al., 2006). Hirschler et al. (2005) reported that WC was a significant predictor for insulin resistance (β=0.050, p=0.001, R^2=0.429) after controlling for diastolic BP, height, BMI and other factors in the sample of 84 children aged 6 to 13. In addition, compared to other surrogates of body fat, researchers reported that WC showed better prediction for cardiovascular health risk. When BMI percentile and WC were included in the same model, WC was a significant predictor for visceral fat (measured by DEXA and CT) and insulin sensitivity (R^2=0.814), while BMI percentile became non-significant (β=0.032, p=0.549) in 145 healthy black and white youth aged 8 to 17 years (Lee et al., 2006). Researchers also concluded in a review paper that, when compared to BMI, WC was better for predicting the risk of obesity related disease (Bray & Bellanger, 2006). Hence, WC is a meaningful indicator for central obesity.

Trends in Obesity by Age

Increasing trends in obesity with age can be found in many previous studies. According to Project HeartBeat!, which was a longitudinal study of cardiovascular disease risk factors in a total of 678 children and adolescents, BMI and waist circumference for both gender increased from the age of 8 to 19 years (Dai, Labarthe, Grunbaum, Harrist, & Mueller, 2002). However, sum of skinfold thickness (SSF) showed different trends; boys decreased and girls increased SSF with age. Similar increasing trend in BMI and waist circumference can be found in a 5-year follow up study in 5,863 adolescents aged 11 to 12 years at baseline (Wardle, Brodersen, Cole, Jarvis, & Boniface, 2006). A group of researchers also reported that BMI increased from the ages of 6-9 to 12-19 years in the sample of 1,302 youth and that a faster increase in BMI was found from the age of 10 to 12 years (Hlaing, Prineas, Zhu, & Leaverton, 2001). Similarly, a faster increase in median BMI from the age of 11 to 13 yeas was also found in a longitudinal study in 4,290 boys and 5,169 girls (Berkey & Colditz, 2007).

Gender difference in SSF has been found in the literature. SSF increased from the ages of 9-10 to 18-19 years in 2,287 black and white girls from the National Heart, Lung, and Blood Institute’s Growth and Health Study (NGHS) (Kimm et al., 2005). Heude et al. (2006) also presented an increase of SSF with age in French girls. But SSF for boys increased from the age of 5 to 11 years then decreased until the age of 17 years.

Summary

No single surrogate of body fat is perfect as a measure of obesity. Clearly, each measure has a significant relationship to health risks related to obesity and it measures different aspects of obesity. For example, skinfold thickness is a sensitive index reflecting subcutaneous fat, waist circumference measures visceral obesity, and BMI is a more reliable indicator of overweight. In addition, while increases in BMI and waist circumference with age and gender difference in SSF have been relatively documented, no research about trend in BMI z score with age was found. Therefore, evaluation of obesity using different surrogates of body fat indexes, including BMI z score, was done to assess obesity with diverse perspectives in the current study.

Physical Activity

Physical activity is an important plausible risk factor for obesity (Crawford & Ball, 2002; Hill & Melanson, 1999). Investigators have reported that the problem of low activity is deeply rooted from childhood. A 5-year follow-up study from childhood to adolescence showed that physically active girls were more likely to be active during puberty, and inactive boys were more likely to be inactive during adolescence (Janz, Dawson, & Mahoney, 2000). A nationally representative longitudinal study also indicated that many adolescents were not physically active and that inactive adolescents became inactive adults (Gordon-Larsen et al., 2004). Hence, empirical data indicate that the problem of low level of physical activity starts from childhood.

A widely accepted definition of physical activity is "any bodily movement produced by skeletal muscles that results in caloric expenditure" (Caspersen, Powell, & Christenson, 1985). In other words, physical activity includes every activity that costs energy regardless of the magnitude of energy expenditure. One specific type of physical activity is exercise. Exercise is defined as "physical activity that is planned, structured, repetitive, and results in the improvement or maintenance of one or more facets of physical fitness" (Caspersen et al., 1985). Thus, physical activity is a diverse spectrum of activities from purposeful exercise to any movement that costs energy regardless of a magnitude.

Physical activity can be assessed in four different dimensions: type (aerobic or anaerobic, and occupational, household, or leisure time activities), intensity (low, moderate, or vigorous activity), frequency (how often it is done), and duration (length of time the activity lasted) (Mahar & Rowe, 2002). Each physical activity measurement, including direct observation, questionnaires reported from self or proxy, accelerometry and heart rate monitoring, assesses different dimensions of physical activity. For example, while questionnaires can measure all four domains of activity, accelerometer can do only intensity, frequency, and duration (Welk, 2002a).

The energy expenditure during physical activity can be indicated as metabolic equivalents (METs), which are very frequently used to measure activity in adults (Ainsworth et al., 2000; Welk, 2002a). A MET of 1, about 3.5 ml/kg/min of oxygen, is resting energy expenditure, so if some activity requires 3 times more oxygen than resting oxygen consumption, then it will be 3 METs. Ainsworth and her colleagues (2000) developed an energy compendium for adults, that is, energy expenditure (MET score) of diverse activity including home activities, hobby, occupation, sport, and religious activities. Therefore, specific activities can be converted into MET score according to the energy compendium

Objective Measure of Physical Activity

Frequently used objective measures of physical activity are accelerometry, heart rate monitoring, and the Doubly Labeled Water (DLW) described below. These measures can be used as gold standards for the development and evaluation of a physical activity questionnaire, which is a relatively subjective measure.

Doubly labeled water (DLW).

The DLW is a method to estimate energy expenditure and metabolic rate using biochemical procedures (Dale, Welk, & Mattews, 2002; Schuit, Schouten, Westerterp, & Saris, 1997). The basic principle of this method is that CO_2 and H_2O are created in the process of energy metabolism (Dale et al., 2002; Starling, 2002). Thus, after ingestion of isotope water ($^2H_2\,^{18}O$), an elimination of ^2H and ^{18}O through body fluid during 10 to 14 days is measured to calculate the amount of CO_2 created, which can convert into energy expenditure (Mahar & Rowe, 2002). While urine, blood, and saliva can be sampled for the procedure, urine collection is frequently used.

Two aspects can be discussed for validity of the DLW as a physical activity measure. First, it is a highly valid indicator if it is intended to measure total energy expenditure or energy expenditure from physical activity over a period of time, when combined with indirect calorimetry. But it is not an accurate measure for total energy expenditure or energy expenditure from physical activity of one specific day. Rather it is an average value of energy expenditure during the period of the examination. Second, DLW cannot measure any specific domain of physical activity such as intensity, frequency, duration, and context (Dale et al., 2002; Mahar & Rowe, 2002). Therefore, if the research focus is physical activity behaviors, then DLW is not a valid measure.

Accelerometry.

Accelerometry is a popular objective measure to assess physical activity by capturing the electronic component of acceleration of the body in specific or multiple dimensions (Dale et al., 2002; Welk, 2002b). It can be measured in free living situations. Intensity of acceleration and counts of acceleration within specific intervals are provided from accelerometry. Energy expenditure can also be derived from it (Trost, McIver, & Pate, 2005; Welk, 2002b).

Reliability of accelerometry has been reported in many studies. Trost et al. (2005) reviewed research about inter-device correlation and stated that intraclass correlation coefficients of 0.71-0.99 were found under lab settings in previous studies. In addition, inter-location reliability has been examined now that accelerometer can be positioned ankle, hip, back, waist, and other possible spots in the body. According to Welk (2002; Trost et al., 2005), previously reported inter-location reliability (intra-class correlation coefficients) ranged from 0.44 to 0.92. That is, there is more variation of inter-location reliability than inter-device reliability. Thus, a small difference in positioning a device can produce large measurement error. Repeatability, which is test-retest reliability, has also been examined. Because of day to day variance or week to weekend variance, a shorter period of recording causes lower reliability. To reach a test-retest reliability of 0.80, the accelerometers should be worn 3 to 5 days for adults and 4 to 9 days for children (Trost et al., 2005).

Construct validity, which is a relationship between a measured variable and other indexes based on theoretical relationships, is well documented. Actual mean counts from accelerometers were significantly related to maximum VO_2 in 30 children aged 8 to 10 years (correlation coefficients: 0.69-0.93) (Eston, Rowlands, & Ingledew, 1998) and in 20 children aged 10 to 14 years (correlation coefficients:0.77 to 0.87) (Trost et al., 1998). Thus, relatively high construct validity has been found in accelerometry in children.

There are several threats to validity of accelerometry. The most important weakness is that accelerometers cannot catch whole body movement. For instance, if it is secured on the hip, then upper body movement cannot be caught. This issue is related to the validity of energy expenditure (EE) estimates. According to the review paper by Westerterp and Plasqui (2004), when EE estimates from accelerometer were compared to EE estimates from the DLW or indirect calorimetry, the correlation coefficients showed vary broad range (0.25-0.91). Similarly, Welk (2002) also pointed out the problem of overestimated or underestimated EE from accelerometry in a review paper and suggested that using raw movement counts may be more valid outcome of accelerometry. Thus, cautious is required when using EE estimates from accelerometry.

Heart rate monitoring.

Heart rate is a direct physiologic indicator related to physical activity because a linear and proportional relationship exists between heart rate and intensity of activity (Dale et al., 2002; Janz, 2002). That is, heart rate (HR) increases while doing physically intensive activity due to the need for increasing oxygen to skeletal muscle (Durant et al., 1993; Janz, 2002).

Several studies examined test-retest reliability of heart rate monitoring. Correlation coefficients (test-retest reliability) within the same day comparison were 0.75-0.92 and day to day comparison correlations were lower (0.56-0.81) in children aged 5 to 7 years (Durant et al., 1993). Test-retest reliability coefficient of 0.70 during 2 consecutive days were reported by other researchers (Janz, Golden, Hansen, & Mahoney, 1992). At least 4 days of recording was recommended based upon the study (Durant et al., 1992). Thus, heart rate monitoring seems to have high test-retest reliability as long as enough duration of recording is guaranteed.

Criterion and construct validity has been reported. When DLW was used as a criterion, the total energy expenditure of groups (not individuals) from heart rate monitoring had ± 20% of difference compared to ones from the DLW (Livingstone et al., 1992). Construct validity was also examined using correlation with fitness measures (Ekelund et al., 2001; Eston et al., 1998; Strath et al., 2000). Heart rate was significantly related to maximum VO_2 in different intensity of activities (correlation coefficients: 0.78-0.86) in children aged 8 to 10 years (Eston et al., 1998). Mean VO_2 was significantly different according to the level of absolute heart rate of 120, 140, and 160 beat per min in the sample of 127 adolescents aged 14 to 15 years (Ekelund et al., 2001). Thus, overall, heart rate monitoring is relatively reliable and valid as a physical activity measure but requires fairly expensive equipment and must be used over multiple days.

Self-Report Measure of Activity

Questionnaires are commonly used to measure physical activity in epidemiologic studies. There are different types of questionnaires: diaries, interviewer-administered questionnaire, self-reported questionnaire, and questionnaire reported by proxy (such as parents) (Kohl, Fulton, & Caspersen, 2000). Regardless of the type, all questionnaires rely on the recall ability of subjects. Thus, due to recall bias, they have a problem of low reliability and validity. In particular, some authors believe that children younger than 10 years of age are not well suited for this method due to restricted cognitive ability (Kohl et al., 2000). A review paper, based on 17 self-reported questionnaires for youth that were already verified using objective physical activity measures in children and adolescent populations, reported that the youngest subjects were 9 years (Sallis & Saelens, 2000).

According to another review paper based on 17 studies examining reliability of questionnaires, test-retest reliability (Pearson, intraclass, or Kappa coefficients) showed very broad ranges from r=0.20 to 0.96. However, the 0.20 of test-retest reliability was from a test-retest 8 year apart and the 0.96 was a correlation coefficient between 2 summary scores (energy expenditure) from the questionnaire, not the questionnaire itself (Kohl et al., 2000). More than half of studies reported test-retest reliability of 0.7 to 0.8. Generally, coefficients from young children are lower than ones from older counterparts, and longer intervals between test-retest shows lower reliability. Thus, if appropriately used, relatively moderate to high reliability can be gained from the questionnaire method.

However, reliability is the minimum requirement for accurate measurement. Validity is much more important issue. Many empirical studies have examined the validity of the questionnaire method. When accelerometry and DLW were used as gold standards, criterion validity (correlation coefficients) of self-reported questionnaires ranged from 0.14 to 0.36 in a review paper based on 17 instruments for children and adolescents (Sallis & Saelens, 2000). Kohl and associates (2000) reported a broader range of criterion validity (correlation coefficients) in their review paper. It was from 0.03 to 0.88, mostly 0.3 to 0.5 in children aged 10 or older. Therefore, criterion validity of self-reported questionnaires is low to moderate at best.

Low criterion validity coefficients of questionnaires do not always mean that questionnaires are not valid (Starling, 2002). The low validity coefficients might be partly due to the gold standard used (Berkey et al., 2000). That is, while DLW measures total energy expenditure or energy expenditure from physical activity (when DLW is combined with calorimetry), questionnaires may measure only some components of physical activity, such as habitual physical activity or leisure time physical activity. Thus, interpretation of criterion validity should be cautious.

A broad range of construct validity was found in previous studies. A low but significant correlation between self-reported instrument and cardiovascular fitness index (VO2 max) has been reported (r=-.23 for girls and r=-.27 for boys) (Berkey et al., 2000). When physical activity logs and accelerometers were compared, low but significant relationships (r=0.15 to 0.24) were also found (Schmidt, Freedson, & Chasan-Taber, 2003). Correlations between 3-day moderate to vigorous activity recall and Actigraph counts were 0265 to 0.314 for girls and 0.34 to 0.27 for boys (McMurray et al., 2004). On the other hand, a few questionnaires showed high construct validity. A high correlation between energy expenditure calculated from the Previous Day Physical Activity Recall (PDPAR) and a pedometer and an accelerometer (r=.77 and .88 each) was reported among seventh to twelfth graders (Weston, Petosa, & Pate, 1997). Thus, it is relatively easy to find moderate to highly reliable questionnaire but difficult to find highly valid one. Due to broad range of reliability and validity in questionnaires, it is important to choose the ones that are proven to be relatively reliable and valid (Goran, 1998).

Objective vs. Self-Report Measures in a Population-Based Study

As noted above, there are several limitations of questionnaires. First, responses depend on the recall ability of participants. Therefore, recall bias influences the accuracy of measurement. Second, it is closely related to the language ability of subjects, so very young children and illiterate people who cannot understand questions are not appropriate populations for the use of questionnaires. Third, although questionnaires can provide information about energy expenditure, the results are subjectively estimated values. Forth, relatively low reliability and validity are the most serious problem of self-reported questionnaire.

Another limitation of the questionnaire method is related to under- or over-reporting. Although no empirical study has been conducted in child and adolescent populations, some researchers found that about 45% of overweight woman over-reported their physical activity (Jakicic, Polley, & Wing, 1998). Additionally, obese adults over-reported their physical activity more than 50% (Lichtman et al., 1992). The problem of over-reporting in physical activity has been explained by awareness of social desirability (Deforche et al., 2003).

Although objective measures are more accurate than self-reported methods, they are difficult to apply in large number of samples in terms of feasibility. A major obstacle is relatively high cost. Secondly, getting cooperation from young subjects is another problem. For instance, devices that show numbers in a monitor, such as pedometer and heart rate monitoring, can make curious children act differently. More importantly, accuracy, which is the strongest strength of objective measures, is not the only important aspect to be considered for a choice of physical activity measurement. For example, while DLW provides very accurate information about energy expenditure, it cannot yield anything about behavior, such as type, intensity, frequency, interval, and context of physical activity (Goran, 1998), which are often of great interest in epidemiologic studies.

The questionnaire method has strength in a population-based study due to its feasibility. It is the most feasible method in population studies chiefly because of low cost. It also takes a relatively short time and little effort to be administered. Thus, the burden on investigators and participants is lower than any other method for measuring physical activity. In addition, it can provide information about multiple dimensions of physical activity (type, intensity, frequency, and duration of physical activity) as well as energy expenditure (calculated from the compendium activity) according to research interest. There are diverse collections of questionnaires. Therefore, according to the choice of specific questionnaires, a diverse range of information can be collected, such as seasonal variation of physical activity, context of the activities, etc.

Trends in Physical Activity by Age

Decrease in physical activity with age has been well documented. According to Kimm et al. (2002), habitual physical activity measured with questionnaire and accelerometer dropped 21% from the ages of 11-12 to 13-14 years. Vigorous activity also decreased from the ages of 11-12 to 15-16 years, when physical activity was measured as how many days per week subjects participated in vigorous activity (Brodersen et al., 2007). Physical activity, measured with survey and pedometer, decreased from the age of 12 to 17 years in 371 adolescents (Duncan, Duncan, Strycker, & Chaumeton, 2007). Hours spent in moderate to vigorous physical activity (MVPA) decreased only for girls in 5-year follow-up study of 806 adolescents aged 11 to 15 years at baseline, (Nelson et al., 2006).

In addition, a greater decrease in vigorous physical activity has been reported. According to Duncan et al. (2007), while number of days spent in hard activity, measured with self-report, decreased 0.55 days, physical activity in a typical week decreased 0.35 days in subjects from the age of 12 to 17 years in a longitudinal study. Vigorous physical activity, measured with accelerometry, decreased faster than MVPA in 401 children aged 8 to 13 years (Sherar, Esliger, Baxter-Jones, & Tremblay, 2007). Thus, while decrease in overall physical activity with age and a greater decrease in vigorous activity have been found in the literature, a few studies included children younger than 10 years old. Additionally, to examine longitudinal trends in different intensity activities respectively (i.e., low, moderate, vigorous, and total physical activity) will be helpful for a better understanding of changes in physical activity during maturation.

Predictors of Physical Activity

Higher physical activity in boys than in girls can be found in the literature. Boys are more active than girls in a cross-sectional analysis in 1,358 children aged 6 to 15 years: odds ratio for being physically active for girls (0.38) and 95% CI (0.29-0.49) (Lasheras, Aznar, Merino, & Lopez, 2001). Male adolescents reported about 11% greater vigorous physical activity than female adolescents (Caspersen et al., 2000). In addition, boys participated more in moderate and vigorous physical activity, measured with accelerometer, than girls in 106 black youth in 6th graders (Trost, Pate, Ward, Saunders, & Riner, 1999b). Longitudinal studies have also shown gender differences in physical activity; girls have lower physical activity and showed a greater decrease with age (46%) than boys (23% decrease) from a 5-year follow-up study in adolescents aged 11 to 12 years at baseline (Brodersen et al., 2007). Another longitudinal study found similar results in 202 adolescents aged from 11 to 13 years (Armstrong, Welsman, & Kirby, 2000).

While many researchers have examined trends in physical activity with age, puberty has been included as a predictor in a few studies. Riddoch et al. (2007b) found a significant negative relationship between puberty and physical activity only for girls: the higher pubertal maturation, the lower physical activity, which was from a bivariate analysis of cross-sectional data in the sample of 5,595 adolescents enrolled in the Avon Longitudinal Study of

Parents and Children. On the contrary, when puberty and age were included in the model, puberty was not significantly related to self-reported physical activity in a cross-sectional analysis in 107 children aged 6 to 13 years (Lindquist, Reynolds, & Goran, 1999).

Although racial differences in physical activity have been reported in the literature, the findings are conflicted. Greater time spent in self-reported physical activity was found in black than white children among 68 children aged 5 to 11 years (Ku, Gower, Hunter, & Goran, 2000). In addition, black girls declined self-reported physical activity faster (100 % decrease) than white girls (64% decrease) in a follow-up study from the ages of 9-10 to 18-19 years in the National Heart, Lung, Blood Institute Growth and Health Study (Kimm et al., 2002). However, some studies have found higher physical activity in white than black youth. White boys reported higher physical activity than black boys in 3,798 subjects aged 11 to 15 years in the Teen Eating for Energy and Nutrition at School Study (Schmitz et al., 2002). In addition, a cross-sectional analysis in a nationally representative sample showed that black youth reported MVPA lower than their white counterpart (Gordon-Larsen, McMurray, & Popkin, 2000). Non-significant difference in physical activity between races has been also reported in the sample of 107 children aged from 6 to 12 years (Lindquist et al., 1999) and 732, 4th and 5th graders (Sallis, Alcaraz, McKenzie, & Hovell, 1999), and 201 high school girls (Neumark-Sztainer, Story, Hannan, Tharp, & Rex, 2003).

As for parental characteristics, relationships between child activity and parental SES have been investigated in many studies. Higher parental SES, combined with job status and education, was significantly and positively associated with physical activity in children aged 6 to 11 years (Starfield, Riley, Witt, & Robertson, 2002). A positive linear relationship between parental SES (education and occupation) and sports activities was found in 2,090 adolescents (Tuinstra, Groothoff, van den Heuvel, & Post, 1998). Gorden-Larsen et al. (2000) also found that youth from families with higher incomes showed higher physical activity levels in a nationally representative samples aged 11 to 21 years.

The relationships between parental obesity and child activity have been investigated in very young children but not in adolescent populations. Parental obesity had no significant relationship to child activity, measured with a questionnaire, in prepubertal girls (mean age: 8.5 ± 0.4) (Treuth, Butte, Puyau, & Adolph, 2000). On the other hand, significant difference in child physical activity, measured with a observation method, between obese and non-obese parent groups was found among preschoolers (Eck, Klesges, Hanson, & Slawson, 1992; Klesges, Eck, Hanson, Haddock, & Klesges, 1990).

Parental activity has been also investigated as a predictor of child physical activity. Conflicting results can be found. Self-reported parental activity was not significantly related to child activity in 900 middle and high school students from the Project EAT (Eating Among Teens) study (McGuire, Hannan, Neumark-Sztainer, Cossrow, & Story, 2002). Child activity measured with a accelerometer was not significantly related to parental activity after adjusting for age, race, and gender (Trost, Pate, Ward, Saunders, & Riner, 1999a). On the contrary, parental activity significantly explained about 46% variance of child activity after controlling for gender, age, and child obesity (b=0.728) (Wrotniak et al., 2007). A significant positive relationship between parental activity and child activity was found in 4th to 6th graders, not in 7th to 9th graders from a nationally representative sample (Sallis, Prochaska, Taylor, Hill, & Geraci, 1999).

Therefore, while gender differences and influence of parental SES on physical activity have been well documented, differences in child physical activity by race, pubertal maturation, parental obesity and parental activity need to be investigated more. Additionally, longitudinal influences of correlates on physical activity can add more information to the current knowledge.

Sedentary Behaviors

Increasingly children live a sedentary life style spending much time in activities, such as TV viewing, video games, and computer use, that involve low physical activity (Livingstone et al., 2003). A nationally representative sample survey (the National Health and Nutrition Examination Survey), including 4063 children aged 8 to 16 years, showed that about 26% of children spent more than 4 hours a day in watching TV (Andersen et al., 1998). TV viewing and video games were one of the top 10 most common activities in middle school students (Harrell et al., 2003) as well as elementary school students in North Carolina (Harrell, Gansky, Bradley, & McMurray, 1997).

The negative effects of sedentary behaviors on health have been reported. Fung et al. (2000) have found a positive relationship between hours of TV viewing and biological markers of obesity and cardiovascular disease risk, such as leptin (r=0.12), low density lipoprotein (r=0.047) and a negative relationship to high density lipoprotein (r=-0.056) in 468 adult male populations. The NHANES data from 1999 to 2000 showed that sedentary behaviors were related to the prevalence of the Metabolic Syndrome in 1,626 US adults, when measured as time spent in front of TV, video, and computer (Ford, Kohl, Mokdad, & Ajani, 2005). A positive association between representative sedentary behaviors, hours of TV viewing, and childhood obesity has also been found (Giammattei et al., 2003; Hancox & Poulton, 2006; Wake, Hesketh, & Waters, 2003).

Measurement of Sedentary Behaviors

According to the Oxford online dictionary, sedentary is rooted from Latin *sedentarius* or *sedere*, and means (1) sitting; seated, (2) tending to sit down a lot; taking little physical exercise, and (3) tending to stay in the same place for much of the time. Therefore, Varo et al. (2003) stated that many researchers have operationalized sedentary behaviors as hours of TV viewing, video game, and computer use.

Questionnaires have frequently been used for the measurement of sedentary behaviors. Schmitz et al. (2004) examined the reliability and validity of a short questionnaire regarding television viewing and computer use among 245 middle school students. Exact agreement (kappa coefficient) was examined by 1- week apart test-retest. Kappa coefficients were 0.55 for weekday TV viewing, 0.51 for weekend TV viewing, and 0.49 for computer use, which indicates moderate reliability as defined by Landis and Koch (1977). Validity was examined using a 7 day log of TV viewing and computer as a comparison. The Spearman correlation coefficients ranged from 0.37 to 0.47. Thus, the questionnaire showed moderate validity.

Similar to physical activity, inaccurate self-report of sedentary behaviors has been documented. In particular, under-reporting from parental report of their child sedentary behaviors have been found (Cheng et al., 2004; Dietz & Strasburger, 1991).

Different measurements for sedentary behaviors have been used in a few studies. Some investigators defined subjects as sedentary if they spent more than 90% of energy expenditure in low or moderate intensity of leisure time physical activity (activities requiring less than 4 METs), which is a ratio score (Gal, Santos, & Barros, 2005; Varo et al., 2003). Reilly and associates (2003) tried to define sedentary behavior using an observation method and accelerometry. Using direct observations, the authors categorized activities of children aged 3 to 4 years as: (a) no movement, (b) stationary with limb movement but no trunk movement, (c) slow trunk movement, and (d) rapid trunk movement. The first two categories were defined as sedentary. Through the comparison to accelerometry and observation, they suggested that less than 1100 counts/min provided high sensitivity (83%) and specificity (82%) to detect sedentary behaviors. This investigator was not able to find further information about a definition of sedentary behavior in terms of energy expenditure in child and adolescent populations.

A frequently used definition of sedentary behaviors is screen time, including TV, video, and computer use. Hence, the current study will use the same definition for the measurement of sedentary behaviors.

Trends in Sedentary Behaviors by Age

Not many studies have been done regarding trends in sedentary behaviors with age. An increasing trend were found in summed hours of TV, video, and computer use (2.5 hours per week for boys and 2.8 hours per week for girls) in a 5-year follow up study in 5836 British adolescents aged 11 to 12 years at baseline (Brodersen et al., 2007). On the other hand, decreasing trends with age have been reported. Hours spent in TV and video viewing for girls decreased and no trend was shown in computer use in girls from a 5-year follow up study in middle school students aged 11 to 15 years at baseline (Nelson et al., 2006). However, boys did not show any trend in TV and video viewing. Instead, hours of computer use for boys increased. There was a decreasing prevalence rate of more than 1 hour per day TV viewing only for girls in the study of Swedish school children from the age of 11 to 13 years (Villard et al., 2007). In addition, they also found a decreasing trend in computer use for both gender. Although it is not longitudinal study, comparisons of screen time (summed hours of TV viewing, video and computer game play) among different age groups also showed a decreasing trend (12-15 years: 23.1, 16-17 years: 20.3 and 18-22 years: 19.8 hours per week) (Gordon-Larsen et al., 1999).

Predictors of Sedentary Behaviors

Racial differences in sedentary behaviors can be found in the literature. Black youth spent more time in front of TV than white counterparts in 107 children aged 6 to 13 years (Lindquist et al., 1999). Hours spent in TV and video games were greater in black than in white youth aged 11 to 15 years (Schmitz et al., 2002). A study in a nationally representative middle and high school students found that black youth spent more time in TV (20.4 hours per week) than white youth (13.1 per week) (Gordon-Larsen et al., 1999). Hours spent in TV and video games were higher in black than white youth from a 5-year follow-up study in middle school students at baseline (Brodersen et al., 2007).

Few studies have examined influences of gender and puberty on sedentary behaviors. Summed hours of TV, video, and computer use were greater in boys than girls (Gordon-Larsen et al., 1999). More matured girls showed more sedentary behaviors in 1,472 samples aged 11 to 12 years (Brodersen et al., 2005) and in middle school girls (Bradley et al., 2000).

Negative relationships between parental SES and sedentary behaviors have been reported in adult and youth populations. A significant negative relationship between SES and hours of TV viewing was found in 8,194 Swedish men and women aged 35 to 74 years (Galobardes, Costanza, Bernstein, Delhumeau, & Morabia, 2003). Parental education was negatively related to hours of TV viewing in 1,350 young children aged 5 to 7 years (Langnase et al., 2002). Schmitz et al. (2002) also found significant negative relationships between TV and video games and parental education only for girls. Higher education in mothers was negatively related to sedentary behaviors in a nationally representative sample from middle and high school (Gordon-Larsen et al., 2000). Higher family income was associated with less likely being sedentary (odds ratio: 0.7, CI:0.59-0.82) in a nationally representative sample of high and middle school students (Gordon-Larsen et al., 2000). From a longitudinal study, a significant negative relationship between SES, derived from postal code information, and sedentary behaviors (TV and video game) was found in youth aged 11 years and this significant relationship became weaker as subjects grew (Brodersen et al., 2007)

On the other hand, a group of researchers have reported that the above mentioned correlates were not significantly related to TV viewing (Lindquist et al., 1999). That is, when gender, race, age, pubertal development, and social class were included in the model, TV viewing was not significantly related any of the variables but only single parent home was significant. Therefore, relatively small number of studies has been examined predictors of sedentary behaviors and the results are conflicting. More studies will provide information about predictors of sedentary behaviors.

Relationships between Physical Activity, Sedentary Behaviors, and Obesity

Risk factors for obesity are inter-related. Knowing how physical activity and sedentary behaviors are associated with each other as well as how each risk factor relates to obesity is important to understand childhood and adolescent obesity.

Physical Activity and Childhood and Adolescent Obesity

Many cross-sectional analyses between objectively measured physical activity and obesity using different measurement methods show an inverse relationship. A significant negative relationship between step counts from pedometer and BMI (r=-0.276 to -0.553 for boys and girls) was found in the sample of 711 US children aged 6 to 12 years (Vincent, Pangrazi, Raustorp, Tomson, & Cuddihy, 2003). Vigorous physical activity measured by accelerometry showed a significant association (β= -0.081, p=0.02, R^2=0.13)) with lower body fat from the sum of 5 skinfold thickness in 780 children aged 9 to 10 years (Ruiz et al., 2006). Vigorous physical activity measured with accelerometry was also negatively related to percentage of body fat (r=-0.38) in 248 children aged 8 to 11 years (Dencker et al., 2006). According to Ekelund et al. (2004), time spent in moderate to vigorous physical activity, which was measured by accelerometer, was significantly associated with log-transformed sum of 5 skinfold thickness (β= -0.0019, p=0.032, r=-0.15) in 1292 children aged 9 to 10. In addition, a case-control comparison between 133 non-obese and 54 obese children indicated that obese children showed lower total daily counts of moderate and vigorous physical activity when accelerometry was used (Trost, Kerr, Ward, & Pate, 2001). Physical activity index, calculated from a difference between heart rate and baseline heart rate divided by a certain interval, was negatively related to body fat in 76 children and adolescents aged 6 to 17 years (Janz et al., 1992). Physical activity measured with DLW showed significant negative relationship to BMI (r=-0.45) in 47 children aged 5 to 10 years (Abbott & Davies, 2004).

In addition, when analyzed in each gender, studies found a significant effect of physical activity on obesity only for boys. When physical activity was measured with DLW, it was significantly associated with BMI (r=-0.37), fat mass (r=-0.46) and percentage of body fat (r=-0.50) for boys but not for girls in the sample of 106 healthy children aged 6 and 9 (E. J. Ball et al., 2001). Similar results (correlation between % body fat and physical activity for boys: r=-0.43) were shown in the sample of 79, 5 to 14 years children when the same DLW method was used (Rush, Plank, Davies, Watson, & Wall, 2003). Hence, cross-sectional analyses including objectively measured physical activity shows an inverse relationship of activity to obesity in youth populations and a possible gender difference in the relationship between physical activity and obesity.

When the questionnaire method is used as a physical activity measure, a negative relationship between activity and obesity has been reported. As for female adults aged 18 to 78, higher level of leisure time physical activity (LTPA) measured with questionnaire was related to having normal BMI and fat measured from skinfold thickness (Ball, Owen, Salmon, Bauman, & Gore, 2001). That is, the odds ratio (OR) for having a normal BMI increased with the level of LTPA (low LTPA: OR 1.71, CI 0.98-2.96; moderate LTPA: OR 2.31, CI 1.28-4.15; high LTPA: OR 2.59, CI 1.34-4.99). In a nationally representative sample of 7216 Canadian children aged 7 to 11, frequency of physical activity measured with questionnaire showed a significant negative relationship to BMI (Tremblay & Willms, 2003). Participating in physical activity more than once a week reduced risk for being overweight (BMI 25-30,10-24% risk reduction) and being obese (BMI 30 or more, 24-43% risk reduction). An activity score calculated from self-report data was inversely associated with BMI ($p<0.0001$) in the sample of 552 girls from fifth to twelfth graders (Wolf et al., 1993). Thus, physical activity measured with questionnaire also showed a negative relationship to obesity in cross-sectional and population-based studies.

Longitudinal studies are needed to clarify a causal relationship between low physical activity and obesity. In a prospective study, self-reported hours of daily physical activity was a significant predictor for girls for 1-year change in BMI among 10,769 boys and girls aged 9 to 14 years (β for girls: -0.0284, p=0.046; β for boys:-0.0261, p=0.094) (Berkey et al., 2000). Another longitudinal study showed that the change of physical activity, measured by self-report at age 14 and 31, predicted change of obesity in 2834 males and 2872 females (Tammelin et al., 2004). That is, males with decreased physical activity between age 14 and 31 had higher odds ratio of becoming overweight (OR 1.49, CI 1.18-1.89) and obese (OR 1.53, CI 0.99-2.37). For females with decreased activity, the odds ratio for being obese was 1.51 (CI 0.94-2.44) and for severe abdominal obesity (waist) was 1.80 (CI 1.13-2.86). In addition, Kimm et al. (2005) reported that when a questionnaire method was used in the sample of 1152 black and 1135 white girls, every 10 MET decrease per week from 9 to10-year-old to 18 to 19- year-old predicted an increase of BMI and sum of skinfold (0.14 and 0.62 for black girls; 0.09 and 0.63 for white girls). Therefore, longitudinal studies indicate that physical activity is a significant predictor for obesity.

However, some longitudinal studies failed to find a significant relationship between physical activity and obesity, which makes it difficult to finalize the relationship. When physical activity and obesity, measured by questionnaire and BMI, percent body fat (bioimpedance), and sum of 4 skinfold thickness, were treated as continuous variables, a graded association was not found in a 3-year follow-up study from 1999 to 2001 in the sample of normal weight 222 boys and 214 girls aged 8 to 18 (Kettaneh et al., 2005). Instead, group comparisons showed that all obesity indicators were higher in the group of girls with decreased moderate physical activity than other girls during follow-up. The group of boys with decreased vigorous activity showed higher sum of 4 skinfold thickness at follow-up than the rest of boys (Kettaneh et al., 2005). Another longitudinal study reported that amount of physical activity was not a significant predictor for change of BMI during follow-up from

1992 to 1996 in the sample of 112 prepubertal subjects (mean age: 8.6, SD: 1.0) (Maffeis et al., 1998). Parental obesity was the only significant factor for child obesity, when eating behavior, physical activity, and parental obesity (BMI) were included in the same model in their research.

Possible reasons for inconsistent results about the relationship between physical activity and obesity are as follows. First, each study controls different factors related to obesity. For instance, parental BMI is one of the most closely related factors to child obesity. However, not all studies controlled for parental obesity. When parental BMI was not included in analyses (i.e., Ball et al., 2001; Tremblay & Willms, 2003), physical activity was a significant predictor of obesity. On the other hand, when parental BMI was included, physical activity was non-significant (Maffeis et al., 1998) or was significant with very little explained variance of obesity (less than 1 %) (Ekelund et al., 2004). Gender is another possible confounder, as previous results presents gender difference of the relationship between physical activity and obesity. Thus, it is important to include possible important underlying factors in analyses to examine how much variance of obesity is explained by physical activity. More importantly, how to deal with the physical activity variable is relevant. Some studies dealt with physical activity as a continuous and others as categorical variable. Significant relationship between activity and obesity has been found using a comparison method between the highest and the lowest groups among tertile, quartile, or quintile.

Intervention studies are another source for determining the relationship between physical activity and obesity. Strong et al. (2005) reviewed 850 articles in children and adolescent populations regarding physical activity intervention programs and concluded that moderate intensity physical activity for 30 to 60 minutes, 3 to 7 days per week can decrease body fat and visceral adiposity in overweight youth but not in normal weight ones. They also suggested that vigorous intensity activity may be required for a beneficial effect on body fat in normal weight children and adolescents.

In sum, a negative relationship between physical activity and obesity in youth can be found in many previous studies. However, most studies have used either BMI or skinfold thickness as a measure of obesity. Thus, studies including other surrogates of fat measures, such as BMI z score and waist circumference, was proposed to broaden the understanding of obesity. In addition, including important underlying factors for obesity is also important to evaluate the uniquely explained variance of obesity by physical activity.

Relationship between intensity of activity and obesity.

More specifically, some researchers have analyzed the relationship between intensity of physical activity and obesity using self-reported activities that were subsequently categorized by intensity of activity (i.e., light, moderate and vigorous physical activity). A survey in a nationally representative sample of 15,143 boys and girls aged 14 to 18 years showed that mean BMI of the highest tertile of frequency of moderate physical activity (MPA) was greater than that of the lowest tertile. The same was true for vigorous physical activity (Eisenmann et al., 2002). Similar results were found in the study of 712 children 9 to 16 years of age in Mexico city when the same method was used (Hernandez et al., 1999).

Studies including an objective measure of activity did not clarify the relationship between intensity of physical activity and obesity. When accelerometry was used for the measurement of physical activity, only time spent in vigorous physical activity (VPA) was reported as a significant factor related to obesity in the sample of 878 girls and boys aged from 11 to 15 years (Patric et al., 2004). Similarly, time spent in vigorous (defined as 2000-3499 counts) and hard activity (defined as 3500 counts), but not in moderate activity, was significantly related to low body fatness (vigorous activity: r=-0.44, p=0.004; hard activity: r=-0.39, p=0.014) in 47 boys and girls aged 5 to 10 years, when an accelerometer was used to measure physical activity (Abbott & Davies, 2004). Ruiz et al. (2006) also reported that vigorous physical activity, but not moderate activity, measured with accelerometry was significantly negatively related to the 5 sum of skinfold thickness in 780 children aged 9 to 10 years. On the contrary, according to the investigation including 1291 children aged 9 to 10 years by Ekelund et al. (2004), moderate to vigorous activities (MVPA), measured with accelerometer, were negatively related to body fat (β=-0.0019, p=0.032) and vigorous activity showed stronger relationship to body fat (β=-0.0034, p=0.015). A significant negative relationship between MVPA and body fat, measured with accelerometer and DXA, was also found in 12-year-old children; odd ratio of the top quintile: 0.03 for boys and 0.36 for girls (Ness et al., 2007). Hence, while vigorous activities have shown significant beneficial effects on obesity, effects of moderate intensity activities on obesity are not clear yet.

The investigation about whether moderately intense activities are negatively related to weight status is an important topic. Moderate activities are easier to achieve than vigorous ones. Thus, if moderate activities can influence obesity, intervention programs targeting increased moderate activities would be more achievable and acceptable to subjects. Hence, there is a need to clarify whether moderate activities have beneficial effects on obesity when considering ease of doing moderate activities.

One of the challenges is the variability of definition of physical activity intensity in youth. Studies have used different definitions. Usually, physical activity can be categorized as light, moderate, and vigorous. For example, Utter et al. (2003) used the cut points of 3 MET for mild, 5 MET for moderate, and 9 MET for strenuous intensity. Gordon-Larsen et al. (2004) used 5 to 8 MET for MVPA in the analysis of data from the National Longitudinal Study of Adolescent Health. Hernandez et al. (1999) defined moderate as 3.5-5.9 MET and vigorous intensity as 6 MET or more. In this study, light physical activity will be 2 or 3 MET, moderate will be 5 MET, and vigorous intensity will be 8 METs, as done by McMurray et al. (2000).

Therefore, analysis of the intensity of physical activity and its effects on obesity is also important for understanding the relationship between obesity and physical activity.

Sedentary Behaviors and Obesity

A positive association between hours of TV viewing and childhood obesity can be found in many studies (Giammattei et al., 2003; Hancox & Poulton, 2006; Wake et al., 2003). Giammattei et al. (2003) reported that amount of TV viewing was positively associated with BMI z score ($r=0.22$, $p<0.01$) and percentage body fat ($r=0.24$, $p<0.01$) in 385 adolescents aged 11 to 13. A significantly increased risk for being overweight (BMI 25 or more) was found in subjects who spent 2-3 hours per day (OR: 1.15, CI: 1.02-1.30) and 3-5 hours per day (OR: 1.36, CI: 1.18-1.58) in front of TV compare to subjects who spent less than 2 hours per day in a representative Canadian sample of 7,260, children 7 to 11 years of age (Tremblay & Willms, 2003). Among 60 obese and non-obese children aged 5 to 11 years, skinfold thickness as well as BMI were significantly greater in the group watching TV more than 1 hour per day (BMI: 22.0 ± 3.3; SSF: 22.2 ± 8.9) than the others (BMI: 19.8 ± 4.1; SSF:

14.3 ± 8.4) (Grund et al., 2001). Hence, cross-sectional analyses showed significant harmful effect of hours of TV viewing on obesity. Watching TV more than 2 hours per day was significantly related to obesity in 15,349 adolescents, graded 9 to 12, from the National Youth Behavior Survey (Lowry, Wechsler, Galuska, Fulton, & Kann, 2002). A representative Canadian sample also showed greater time in TV in obese youth than normal weight youth (Janssen, Katzmarzyk, Boyce et al., 2004). Similarly, 2 or more hours per day TV viewing was significantly related to being overweight from the National Nutrition Survey in Colombia (Gomez et al., 2007).

Longitudinal studies have also shown a positive relationship between obesity and TV viewing. In a prospective study, time spent in front of TV was a significant predictor for 3-year change in BMI among 1037 children with correlation coefficients ranging from 0.07 to 0.14, which is regarded as a small effect size (Hancox & Poulton, 2006). When TV viewing was observed from 5 to 15 years of age and the outcome was health risk at age 26, longer hours of TV viewing during childhood and adolescence showed long-lasting effects on health in later life, including overweight and elevated cholesterol, among about 1000 subjects (Hancox, Milne, & Poulton, 2004). Greater BMI increase (girls: 0.0372 ± 0.0106; boys: 0.0384 ± 0.0101) was found in subjects who watched TV more in a 1-year follow-up study in 6149 girls and 4260 boys aged 9 to 14 years, (Berkey et al., 2000). Greater BMI percentile increase was observed in students with longer hours of TV viewing in a 3-year follow up study among 2223 adolescents (Kaur, Choi, Mayo, & Harris, 2003). Therefore, negative effects of long hours of TV viewing on obesity and health have been found in previous longitudinal studies.

Intervention studies, intended to reduce TV viewing hours, have also shown effects on reducing obesity. Gortmarker et al. (1999) investigated a longitudinal effect of reduced TV watching hours on obesity using a randomized and controlled design. The intervention was found to be effective in reducing obesity only for girls (OR 0.47, CI 0.24-0.93), when obesity was defined as age- and gender- specific 85^{th} percentile or greater BMI and triceps skinfold thickness. Robinson (1999) also presented intervention effects of reduced TV hours in 192, 3^{rd} to 4^{th} graders. That is, BMI, sum of skinfold, and waist circumference were significantly reduced in girls and boys (adjusted mean change for BMI: -0.45, CI -0.73 to -0.17; SSF: -1.47, CI -2.41 to -0.54; WC: -0.02, CI -0.03 to -0.01). Hence, the association between TV viewing and obesity is supported by many cross-sectional, prospective and intervention studies.

However, not all studies have shown significant effects of TV viewing on obesity. When hours of TV viewing was categorized into 5 groups, no significant relationship to BMI was found (p for trend: 0.47) among 552 girls, 5^{th} to 12^{th} graders (Wolf et al., 1993). The authors explained that no statistical significance of trend was because the lowest quintile TV viewing group had the greatest mean BMI. It reveals a possible significant curve linear relationship between TV viewing and BMI. Robinson et al. (1993) also reported that hours of TV watching were not associated with baseline and longitudinal change of BMI and sum of skinfold thickness in cross-sectional analysis of baseline data in 671, 6^{th} and 7^{th} graders and in longitudinal analysis of 279 subjects. In addition, a follow-up study from preschool children (mean age: 4) to early adolescence (mean age: 11.1) using mix effects model analysis showed that hours of TV viewing were a predictor of changes in BMI and sum of five skinfold thickness but hours of TV viewing became non-significant after controlling for physical activity measured by accelerometry (Proctor et al., 2003). According to Giammattei et al. (2003), when ethnicity was included in a model, TV viewing was not significant but ethnicity and sweet drink intake were significantly related to obesity. A summed screen time (TV, video tapes, and playing video game) was not related to BMI z score with or without controlling for parental obesity in 173 girls aged 8 to 12 from 4-year follow up study (Must et al., 2007). Therefore, a few aspects need to be considered in future studies to assess the unique influence of TV viewing on obesity: how to deal with the variable of TV viewing, for instance, as a categorical or continuous variable; what to include in analysis models as controlling variables, i.e., race, gender, SES, eating behaviors, and physical activity level.

Video games and use of computers are also popular sedentary behaviors in youth. According to Christakis et al. (2004), children spend more time in video and computer use than in TV viewing. Similar to TV viewing, video games and computer use have been measured as frequency or hours spent in those behaviors. Sometimes video games and computer use have been included in analyses as separate variables so that relationships between each behavior and obesity can be assessed. More frequently, hours of TV viewing, video, and computer use have been aggregated as one variable, such as total screen time, in analyses. While electronic games more than 1 hour per day was significantly related to obesity, TV or computer use were not significantly related to obesity. Odds ration of being obese were 0.45 for boys and 0.57 for girls in less than 1 hour per day electronic game use (Carvalhal, Padez, Moreira, & Rosado, 2007).

Summed hours of TV viewing, video game, and computer use have been reported as a significant factor for obesity. Berkey et al. (2000) found that a summed time spent in front of TV, video and computer games was closely associated with an increased BMI in a year later

(β=0.0372) among 10,769 boys and girls aged 9 to 14. Utter et al. (2003) also reported that mean BMI for boys and girls was significantly different ($p<0.05$) among tertile groups of summed hours of TV and video use (BMI for boys: 23.3±0.2 for the highest, 23.2±0.1 for the middle, and 22.6±0.3 for the lowest group; BMI for girls: 23.8±0.2 for the highest, 23.3±0.2 for the middle, and 22.8±0.2 for the lowest group) in the sample of 4746 middle and high school students. When normal and overweight groups were compared, the overweight group children spent more time in video and computer game play (0.33 vs. 1.25, p=0.03) in 54 children aged 8 to 12 years (Crooks, 2000). Electronic game play more than 1 hour per day reported by parents was significantly related to BMI in nationally representative sample of Portuguese ($p<0.001$ for boys and $p<0.029$ for girls) aged 7 to 9 years (Carvalhal et al., 2007). One or more hours spent in front of a screen was significantly associated with increased risk for being obese (1-3 hours: OR 1.28, CI 1.02-1.61; 3-6 hours: OR 1.30, CI 1.02-1.65; more than 6 hours: OR 1.35, CI 1.04-1.74) in 4298, fifth graders in Nova Scotia (Veugelers & Fitzgerald, 2005).

When time spent only in computer or in video game play was used separately in analyses, inconsistent findings have been reported. Some studies have presented a significant relationship to obesity. A comparison between 54 overweight and non-overweight children aged 8 to 12 showed that overweight children engaged in video or computer game play more frequently than non-overweight ones (non-overweight: 0.33±0.72 vs. overweight: 1.25±1.29, p=0.03) (Crooks, 2000). Those who played video games more than once a week showed elevated risk for being overweight (BMI cut point:25) (OR: 1.19, CI 1.07-1.33) in a representative Canadian sample aged 7 to 11 (Tremblay & Willms, 2003).

On the contrary, some researchers failed to find a significant effect of computer use. Computer use and weight status did not show a significant linear or curve linear relationship in the sample of 2831 adolescents aged 9 to 12 (Vandewater, Shim, & Caplovitz, 2004). There was no significant association between video games and obesity and between computer use and obesity among 712 adolescents aged 9 to 16 in Mexico City area, while TV viewing showed a significant association with obesity in the same population (Hernandez et al., 1999). Similarly, Kautiainen et al. (2005) presented significant effects of TV viewing and non-significant effects of digital game play on the elevated prevalence of overweight in the sample of 6,515 girls, aged 14, 16, and 18 (Kautiainen et al., 2005). In addition, Giammattei et al. (2003) reported that non-significant correlation coefficient between computer use and BMI z score ($r=0.04$, $p=0.44$) and between video game play and percentage body fat ($r<0.01$, $p=0.87$). Utter et al. (2003) also reported that mean BMI of the highest, middle, and the lowest computer use groups for boys was not significantly different (23.1±0.2 for the highest, 23.0±0.2 for the middle, and 23.2±0.2 for the lowest group), while girls showed a significant difference of BMI between the tertile groups (24.1±0.3 for the highest, 23.3±0.2 for the middle, and 23.1±0.2 for the lowest group).

In short, a common sedentary behavior, TV viewing, has been reported as a significant factor for obesity in previous literature. However, video games and computer use may have different energy expenditure than TV watching, as the non-significant effect of video and computer use on obesity has been reported frequently. For example, Harrell and associates (2005) reported that energy expenditure while watching TV (age adjusted metabolic equivalents: 1.02-1.06) in children and adolescents was lower than energy expenditure when playing video games (age adjusted metabolic equivalents: 1.22-1.28 for sitting and 1.45-1.47 for standing). Thus, using different measures for sedentary behaviors, such as separate measures for TV, video games, or computer use will provide more information. In addition, obesity has been frequently defined using BMI and skinfold thickness in previous investigations to assess the relationships between sedentary behaviors and obesity. Waist circumference and standardized BMI will be helpful to understand the relationship between sedentary behaviors and obesity in a different perspective.

Physical Activity and Sedentary Behaviors

Significant negative relationships between physical activity and sedentary behaviors have been presented in many studies using diverse measurement methods (DuRant et al., 1994; Katzmarzyk et al., 1998; Marshall et al., 2004; Pate et al., 1997; Strauss et al., 2001; Vilhjalmsson & Thorlindsson, 1998). In a cross-sectional study of 104 first graders (median age: 5.4), energy expenditure of physical activity, measured by DLW and accelerometry, and time spent in sedentary behaviors, measured with accelerometry, were negatively correlated (r=-0.33) (Montgomery et al., 2004). A population study in a nationally representative sample of 15,143 high school students aged 14 to 18 (the Youth Risk Behavior Survey) found that elevated levels of moderate to vigorous physical activity, measured by questionnaire, were related to less TV viewing (Eisenmann et al., 2002). Objectively measured physical activity using accelerometry was also inversely associated with video game play in 102 adolescents (mean age 15) (r=-0.38 for boys and -0.55 for girls) (Janz & Mahoney, 1997). In a review paper based on 52 independent samples aged 7 to 18 years, mean sample-weighted effect size between TV viewing and physical activity and between video & computer game and physical activity was -0.0096 and -1.104 respectively (Marshall et al., 2004).

On the other hand, other researchers claimed that active and sedentary behaviors were not negatively associated (Allision, 2002; Brodersen et al., 2005; Ekelund et al., 2006; Grund et al., 2001; Parsons et al., 2005; Wolf et al., 1993). Adolescents in the highest and the lowest quintile of TV viewing hours showed no significant difference in energy expenditure and moderate to vigorous physical activity, measured with self-report activity log in the sample of 423 males and 361 females aged 9 to 18 (Katzmarzyk et al., 1998). A British birth cohort study showed that physical activity and TV viewing were significantly related to BMI when both factors were included in the model but they were not related to each other in 11-year-old girls (Parsons et al., 2005). Utter et al. (2003) failed to find a significant difference of physical activity among the highest, middle, and the lowest groups of TV viewing in 4746 middle and high school students. Hours of TV viewing and video games were not related to physical activity in a cross-sectional analysis among 743 high school students (Feldman, Barnett, Shrier, Rossignol, & Abenhaim, 2003). Correlation between physical activity, measured with accelerometry, and TV viewing was not significantly related ($r=0.012$, $p=0.58$) in 1921 boys and girls aged 9-10 and 15-16 years (Ekelund et al., 2006).Vigorous physical activity measured with survey was also not correlated with TV in 1,041 Canadian boys and girls graded 9 to 11 (Allision, 2002) and in 4360 boys and girls aged 11 to 12 years (Brodersen et al., 2005). Longitudinal relationship between TV and moderate to vigorous physical activity was not significantly related in Canadian sample (Neumark-Sztainer et al., 2003) and in US sample (Taveras et al., 2007).

Non-negative relationship between sedentary behaviors and physical activity have supported by the results that individual can be sedentary and active at the same time. According to te Velde et al. (2007), boys spent more time in TV viewing and computer use than girls but also physically activity than girls in 12,538 adolescents aged 11 years. The National Youth Behavior Survey also showed that black youth spent more time in watching TV and physically more active than white counterpart in 15,349 high school students (Lowry et al., 2002). Adolescents who spent more time in TV viewing participated more in moderate physical activity in 92 children aged 10 to 16 years (Strauss et al., 2001).

Unlike hours of TV viewing, computer use seems to have a more complicated relationship to physical activity. A positive relationship between computer use and physical activity has been reported. Spearman correlation between computer use and physical activity, measured by questionnaire, was 0.16 for weekdays and 0.10 for the weekend in 500, 7^{th} to 12^{th} graders (mean age:14.6) (Santos et al., 2005). The authors provided as a possible reason that the nature of computer use is different from TV viewing, in that computer use is associated with working, not playing, in this age population. Utter et al. (2003) also found similar results only for girls. That is, the highest computer use group showed a greater mean leisure time physical activity (52.5 ± 1.8 kcal/kg/week) than the middle (47.6 ± 1.3 kcal/kg/week) and the lowest group (46.4 ± 1.1 kcal/kg/week). For boys, the middle group (67.0 ± 1.4 kcal/kg/week) showed a greater mean of physical activity than the highest (63.0 ± 1.7 kcal/kg/week) and the lowest group (63.1 ± 1.38 kcal/kg/week). In addition, more computer use was related to being active only for males in 7982 youth aged 12 to 19 years from the Canadian Community Health Survey (Koezuka et al., 2006). That is, compared to boys with no computer use, less than 6 hours computer use per week showed odds ratio of 0.61 (0.47-0.79) for being physically inactive.

Thus, the relationship between physical activity and sedentary behaviors is not clear yet, which makes it difficult to weigh the relative importance of those health behaviors on obesity. In addition, investigation of interrelationships between sedentary behaviors and physical activity needs to be done by each sedentary behavior. A clearer understanding of inter-relationships between physical activity and sedentary behaviors is needed to guide intervention and clinical recommendations. For instance, if activity and sedentary behaviors are negatively related, intervening on one aspect may be effective. If activity and sedentary behaviors are not related, which means that physical activity and sedentary behaviors may not be in the same continuum of the level of activity but in two different dimensions, we need to assess activity and sedentary patterns of each child so that customized intervention will be more effective.

Other Correlates for Obesity

It is important to include other covariates in analysis to examine the unique influence of physical activity and sedentary behaviors on obesity. This review includes eating behaviors, parental influences, race, gender, and puberty as important covariates for obesity,

Eating Behaviors and Obesity

Unhealthy eating behaviors have been reported as one of the risk factors for obesity. According to Nielsen et al. (2002), nationally representative data measured during 1977-1978 and 1994-1996 in 63,380 subjects from age 2 and up, shows that total energy intake, snack intake, and frequency of eating-out have increased in all age groups for the last 20 years (Nielsen, Siega-Riz, & Popkin, 2002). In particular, consumption of fast foods and soft drinks by youth has rapidly increased (St-Onge, Keller, & Heymsfield, 2003).This means that more and more children and adolescents have unhealthy eating behaviors.

Eating behaviors of adolescents are very problematic when compared to the national guidelines. About a half of adolescents did not consume fruits and vegetables compared to the guidelines of at least 5 a day and about 70 percent of them did not eat even 1 serving of a dairy product a day (Munoz, Krebs-Smith, Ballard-Barbash, & Cleveland, 1997; Story, Neumark-Sztainer, & French, 2002). The percentage of energy intake from dietary fat was reported as 40 % (the guideline: less than 30%) in youths (Munoz et al., 1997; Paulus, Saint-Remy, & Jeanjean, 2001). In addition, the prevalence of youth who met the Healthy People 2010 recommendations was much lower than the targeted prevalence in every food category in 4746 adolescents aged 11 to 18 (Neumark-Sztainer et al., 2002). Hence, comparisons of results of their surveys to the food recommendations suggest that the US youth eat too much fat, fast foods, and soft drinks and too few fruits and vegetables.

Conflicting results have been reported regarding relationships between eating behaviors and obesity in youth. Some researchers found no significant relationship between adolescent obesity and unhealthy eating habits, such as low intakes of fruits and vegetables, and high intakes of soft drinks, fast foods, and fat, from descriptive studies (Field et al., 2003; Janssen et al., 2005; Willett, 2002). According to Maffeis et al. (2000), diet composition was not associated with obesity when adjusting for parental obesity in 530 children aged 7 to 11 years (Maffeis et al., 2000). Data from a comparison study among 137,593 adolescents aged 10-16 in 34 countries data failed to find a significant relationship between obesity and intake of fruit and vegetables, and soft drinks; there was a significant relationship between sweets (candy and chocolate) and BMI (Janssen et al., 2005).

On the other hand, other researchers have reported that poor eating habits are one of the critical risk factors for obesity. A result from an animal experiment was one proof, which showed that high fat diet can induce obesity in rats (Bray, Paeratakul, & Popkin, 2004; Oscai, 1982). Descriptive studies found significant associations between unhealthy eating behaviors and obesity in youth: significantly positive relationships between sweetened drinks and fast foods and obesity (Murray et al., 2005; Nicklas et al., 2003). The Bogalusa Heart Study (n=1562 children aged 10 years) showed that sweetened beverages, snacks, and low quality foods (including fats, oils, sweets, and salty snacks) were positively related to obesity in young adolescents (Nicklas et al., 2003). When they used the definition of overweight as 85^{th} or more age- and gender- specific BMI, odds ratios for being overweight were 1.33 (CI: 1.12-1.57) in sweetened beverage, 1.24 (CI: 1.02 to 1.50) in snacks, and 1.35 (CI: 1.08-1.68) in low quality food. Low BMI was associated with higher intake of vegetable (r=-0.211) in 210 African American girls aged 8 to 10 years in a cross-sectional study (Cullen et al., 2004).

Effective dietary interventions focusing on healthy eating provide another indirect proof for poor eating habits as a risk factor for obesity. High fruits and vegetables and low fat and sugar intakes produced beneficial effects on reducing body weight (Epstein et al., 2001; Glenny, O'Meara, Melville, Sheldon, & Wilson, 1997). Bray and Popkin (1998) concluded in a review paper based on previous 28 clinical trials (mostly adults and small number of sample size) that 10% less fat intake can decrease weight 16 gram/day.

On the contrary, many dietary intervention studies failed to connect change of eating behaviors to health benefits including obesity, while they succeeded in changing unhealthy eating behaviors into healthy ones. According to a review paper based on 21 intervention trials from 1966 to 2001 (intervention for adults), many intervention trials showed positive effects to reduce saturated fat intake and to increase fruit and vegetable intake, but the effects on health outcomes were not clear (Pignone et al., 2003).

In short, it is clear that many children and adolescents have unhealthy eating behaviors. However, it is difficult to clearly identify the relationships between eating behaviors and obesity. This is partly because there are many different types of unhealthy eating behaviors, such as high fat and soft drink intake, low fruit and vegetable intake, frequent eating-out and fast food intake. It is also because objective measurement for eating behaviors is rare. All studies reviewed in this chapter measured eating behaviors with questionnaires or diaries from self-report or proxy (such as parents).

However, eating behavior cannot be neglected in obesity research. As mentioned above, obesity is a result of an imbalance between energy intake and consumption. According to Nemet et al. (2005), a combined intervention program including dietary behavior and physical activity components is more effective than a single approach intervention. Thus, dietary behavior was included in models as a covariate in the current study. In particular, intake of sweet drinks was used due to simplicity of measurement and empirical proofs.

Recently many researchers are focusing on the effects of sweet drinks on obesity. According to a review paper by Dehghan et al (2005), the United State Department of Agriculture (USDA) survey shows 118% increase of carbonated drink consumption per person between 1970 and 1997. The authors commented that soft drink intake is related to elevated risks for obesity and type 2 diabetes among youth populations.

In an empirical study, sweetened beverages, including soft drinks, fruit flavored drinks and tea and coffee, were significantly and positively associated with overweight (BMI 85% or more) when 24 hour dietary recall was used in a sample of 1562 children aged 10 years (overall: OR1.33, CI 1.12 to 1.57; white male: OR 1.68, CI 1.21 to 2.33; white female:

OR 1.53, CI 1.05 to 2.22; black male: OR 1.02, CI 0.72 to 1.46; black female: OR 1.00, CI 0.73 to 1.35) (Nicklas et al., 2003). BMI was increased by 0.24 unit (kg/m^2; CI 0.10 to 0.39) with increased serving frequency of sweet drinks in a follow-up study from 1995 to 1997 in 548 school children (mean age: 11.7, SD 0.8) (Ludwig, Peterson, & Gortmaker, 2001). In a review paper based on 15 cross-sectional, 10 longitudinal, and 5 experimental studies, Malik et al. (2006) concluded that intake of sweet drinks is positively related to obesity in children and adults.

Parental (Familial) Influence on Obesity

Familial factors have been reported as important risk factors for child obesity. As Baur (2002) explained, obesity is a result of the inter-relation between genetic, metabolic, behavioral and environmental, and lifestyle factors. Family members share genetic, environmental, and lifestyle similarity. Well-known parental factors for child obesity are parental SES, obesity, and activity level.

Parental socioeconomic status and child obesity.

Parental socioeconomic status (SES) has been presented as a risk factor for childhood obesity. SES can be measured with education, occupation, and income. When SES is represented with education level, which is the highest education achieved by mother or father, a significant negative relationship to child obesity has been reported. Kimm et al. (1996) found that odds ratio for being obese (child) of parents with some college education parents was 0.86 (CI 0.56-1.32) and that of college graduate parents was 0.53 (CI 0.33-0.85), compared to high school or less than high school graduate parents in white girls from the analysis of the Growth and Health Study in a sample of 2379 white and black girls aged 9 to

10 years. The highest education level of either mother or father was also inversely related to overweight in children in a German sample of children aged 5 to 7 (Langnase et al., 2002). That is, compared with parents with advanced high education, parents had equal to and less than 9 years of education showed much higher odds ratio for being overweight of child (boys: OR 3.1, CI 1.7-5.4; girls: OR 2.3, CI 1.2-4.3). Similar results were found in another German sample in the total of 2631, 5 to 7 years children (Danielzik, Czerwinski-Mast, Langnase, Dilba, & Muller, 2004).

Income has also been used for the measurement of SES. In a review paper, Agras and Mascola (2005) stated that family income has a protective effect on childhood overweight. In the sample of 1,871 high school students, subjects from a high income district showed more frequent PE per week (mean ± SD of white high SES group: 3.7 ± 2.4; white low SES group: 2.8 ± 2.7) and higher frequency of vigorous exercise during PE (white high SES group: 5.0 ± 0.9; white low SES group: 3.6 ± 2.5) compared to students from a low income district (Sallis, Zakarian, Hovell, & Hofstetter, 1996).

Parental occupation is another indicator for SES. A significantly negative relationship between occupation and obesity has been found. That is, the mean BMI of a professional occupational group was 25.9 and that of an unskilled manual occupational group was 27.2 in an adult female population (Wardle, Waller, & Jarvis, 2002). Similar to income, parental occupation seems to have a protective effect on obesity. According to Tammeline et al. (2003), the prevalence of physical inactivity in children was higher in children with lower status of father's occupation in 3069 boys at age 14: skilled professional 13.5%, skilled worker 17.1%, unskilled worker 20.4%, and farmer 24.2%.

Parental obesity.

Parental obesity has been reported as a strong risk factor for obesity in their children. A prospective study in the sample of 150 children, followed up from birth to 9.5 years of age, showed that parental overweight predicted childhood overweight (r=0.38) (Agras, Hammer, McNicholas, & Kraemer, 2004). In another longitudinal study, which followed a sample of 155 healthy boys and girls from 2 to 20 years of age, standardized BMI score of boys (standard deviation of BMI using age and gender specific BMI percentile curve) was correlated to BMI of the mother (r=0.26-0.40) and father (r=0.20-0.42). For girls, BMI of the father was significantly associated with standardized BMI score of the child (r=0.33-0.51), but BMI of the mother was only significantly related to standardized BMI score of the child at age 8 or older (Magarey, Daniels, Boulton, & Cockington, 2003). In addition, a secondary data analysis of a family-based intervention study showed that change of parental BMI z score between pre and post observations significantly predicted change of child BMI z score (R^2=11.6% at 6 months and 3.8% at 24 months) in 142 families with obese children aged 8 to 12 (Wrotniak, Epstein, Paluch, & Roemmich, 2004). In 1350 German children aged 5 to 7 (Langnase et al., 2002), overweight parents showed a higher prevalence of having overweight children (27.9% of child overweight) than parents who were not overweight (normal weight mother: 16.7% of child overweight; underweight mother: 12.8% of child overweight). Hence, close relationships between parental and child obesity have been reported.

Parental activity level.

Parental activity may influence child obesity. Although an exact mechanism of how parental activity level is associated with child obesity is not clear, one of the possible pathways is through the relationship between parent and child activities. Parental and child activities, reported by parents, showed a significantly positive correlation among 59 healthy children aged 6 to 9 (Bogaert et al., 2003). That is, correlation of percent time spent in MVPA between mother and daughter was 0.44 (p=0.03) and correlation of light intensity activity of father and children was 0.43 (p=0.005). According to Gilmer et al.(2003), the activity of 113 children of parents with premature coronary heart disease related to the level of activity of their fathers. Troiano and Flegal (1998) explained the relationship between parent and child activities as shared family environment.

Race, Health Behaviors, and Obesity

Black children and adolescents are more obese than white ones. The NHANES data from 2003 to 2004 indicated that prevalence of overweight (95^{th} or greater than age and gender specific BMI percentile) was 21.8% for black and 17.3% for white children aged 12 to 19 (Ogden et al., 2006). In the CHIC study, black boys and girls also showed higher prevalence of obesity than white boys and girls aged 10 to 16 in North Carolina (mean BMI: black female 24.0 ± 6.2, black male 22.3 ± 5.0; white female 21.7 ± 4.6, white male 21.6 ± 4.8) (McMurray et al., 2000). Haas et al. (2003) also reported a higher likelihood of being overweight in black than in white youth.

Racial difference in prevalence of obesity may be due to differences in health behaviors. Overall, white adolescents show higher physical activity levels than other races (Sallis et al., 1993). According to the NHANES III data, prevalence of 3 or more times of weekly exercise was 69.4% in black girls, 77.6% in black boys, 77.1% in white girls, 87.9% in white boys (Andersen et al., 1998). In addition, black children spent more time in front of the TV (2.2 hours /day) and a lower prevalence of team activity participation (38%) than white children (1.8 hours /day; 58%) in a sample of 107 boys and girls aged 6.5 to 13 (Lindquist et al., 1999). In a tracking study of 2379 girls, Kimm et al. (2002) reported more decline in physical activity among black girls (100% decline) than white girls (64%) during 10 years from 9-10 years to 18-29 years of age. Black adolescents also spent more time in TV viewing and video games than white adolescents during school days and non-school days in a sample of 2389 adolescents aged 10 to 16 years (McMurray et al., 2000).

In addition, black youth showed unhealthy eating behaviors compared with white youth. Black youth had higher fat food availability (Agras & Mascola, 2005; Granner et al., 2004; Hannon, Bowen, Moinpour, & McLerran, 2003; Nicklas et al., 2003), while white adolescents had more access to healthy foods (Granner et al., 2004). According to Neumark-Sztainer et al. (2002), white adolescents had lower fat intake than black adolescents.

Gender, Health Behaviors, and Obesity

Gender is another important demographic variable related to the level of physical activity, which is closely related to obesity. Overall, females show lower physical activity level than males in many investigations. When sedentary was defined as children whose top 3 activities included 2 or more activities with less than 2 or 3 METs, 42.1 to 66.2% of girls were sedentary, while 25.2 to 43.5% of boys were sedentary in the sample of 3rd to 10th graders (Bradley et al., 2000). Tammelin et al. (2004) evaluated physical activity at the ages of 14 and 31 among 5,706 Finnish males and females. At the age of 14, more boys participated in sports daily or every other day (22.8%; 25.2%) than girls (12.7%; 14.6%). Caspersen et al. (2000) reported that 16.8% of girls and 10.5% of boys were inactive at age 17 from the analysis of 1992 Youth Health Behavior Survey. Sallis et al. (1996) also found that time spent in vigorous activity out of school per week for boys was 3.8 hours and for girls was 2.6 hours in 1634 multi-ethnic adolescents populations. In addition, a nationally representative cross-sectional study in the sample of 4063 children aged 8 to 16 years (the NHANES III) showed that 84.6% of boys did vigorous intensity activity, while 74.5% of girls did (Andersen et al., 1998).

Gender differences can also be found in the relationship between activity and obesity and between sedentary behaviors and obesity. Crespo et al. (2001) presented a significant positive relationship between TV viewing and obesity only for girls, not for boys in 4069, 8 to 16 years of children. Ball et al. (2001) found that physical activity was significantly related to obesity for boys ($r=-0.37$, $p<0.01$), but not for girls in healthy 106 children. Gorden-Larsen et al. (2002) reported that the odds ratios for being obese in sedentary children were 1.52 (CI 1.08 to 2.14) for boys and 2.45 (CI 1.51 to 3.97) for girls, and the odd ratio for being obese in active children (doing MVPA) were 0.81 (CI 0.76 to 0.87) for white boys, 0.86 (CI 0.76 to 0.98) for black boys, and 0.88 (0.78 to 0.99) for black girls. This means that for girls, sedentary behaviors explain obesity better than physical activity. McMurray et al. (2000) also reported that each gender had different predictors for obesity. That is, for males, weight was more closely associated with exercise than with TV or video games, and for girls, video and exercise were not related to obesity, rather SES and ethnicity may be more important. Thus, gender should be included in studies about physical activity, sedentary behaviors, and obesity.

Puberty and Obesity

Puberty is a life transition period, which involves changes in psychological, physiological, and behavioral aspects. In particular, changes of body composition and weight status are associated with pubertal development (Dunger, Ahmed, & Ong, 2006; Rodriguez et al., 2004; Rogol, Roemmich, & Clark, 2002).

Johnson et al. (2006) describe the patterns of normal growth in young populations. According to them, preschoolers experienced a decrease in BMI and a BMI level rebound during age 4 to 7. During puberty, boys and girls show different growth patterns of adipose cells. Boys show a slight increase in fat accumulation that is followed by a decrease during adolescence, which seems to be the results of increased muscle development. For girls, fat accumulation increases steadily throughout puberty.

In addition, weight status and puberty showed close relationships. Overweight girls begin puberty earlier than others and gain more fat during that period compared to non-obese girls (Biro, Khoury, & Morrison, 2006; Hammar, 1975; Johnson et al., 2006). Boys with lower adiposity (more muscle mass) is related to earlier maturation in boys (Biro et al., 2006).

Empirical studies show changes of fat composition in each gender during puberty. McCarthy et al. (2006) reported that adiposity growth curves, derived from the measurement using bio-impedance in the sample of 2085 boys and girls aged 5 to 18 years, were similar in both sex before puberty. However, the curves were different during puberty. That is, boys decreased fatness with maturation and girls gained fatness continuously. Vizmanos and Marti-Henneberg (2000) also found that boys with smaller BMI had earlier onset of puberty and boys with later onset of puberty had greater BMI in the sample of 469 children aged 10 to 15. In contrast, girls did not show significant difference in BMI at the onset of puberty regardless of early or late onset.

Thus, while not many studies have included puberty in analyses, pubertal maturation should be included in obesity research in young populations a puberty has distinct effects on body fat.

Conclusions

While many researchers have investigated predictors of physical activity, relatively few researchers have examined how the relationships between predictors and physical activity change as children grow older. In addition, few studies have looked correlates of sedentary behaviors as well as longitudinal relationships between correlates and sedentary behaviors in child and adolescent populations.

As for the relationships between physical activity and obesity, the literature, including cross-sectional, longitudinal, and intervention studies shows that children and adolescents with low physical activity are at risk for obesity. In particular, vigorous intensity activity is one of strong predictors for low body fatness, while effects of moderate intensity activity on obesity are still controversial.

This review also shows that sedentary behavior, especially, hours of TV viewing, is a risk factor for obesity, even though some researchers have suggested that TV viewing has a small effect on obesity (Agras & Mascola, 2005; Marshall et al., 2004). Other sedentary behaviors, video games and computer use have not shown a consistent relationship to obesity.

Therefore, it is important to investigate the association between activities of different intensity and childhood obesity for a clearer understanding of the relationships between physical activity and obesity. In the analysis of the longitudinal relationship between obesity and sedentary behaviors, using three popular sedentary behaviors (TV viewing, video games, and computer use) separately will provide more information than is currently available.

To assess the extent of obesity explained by either physical activity or sedentary behaviors, possible confounders need to be included in models. Including age, gender, race, puberty, parental influence, and eating behavior, which have shown significant relationships to child obesity, in analysis can help clarify the relationships. At the same time, including those variables in analysis will provide the relative importance of physical activity and sedentary behaviors may differ by gender or by race and etc, which would also have implications for interventions. In particular, not many studies have included pubertal maturation. As mentioned earlier, puberty is a critical period for body composition change. Hence, it is essential to include pubertal development in obesity research in adolescent populations.

In addition, it is also important to assess physical activity, sedentary behaviors, and obesity with more diverse methods. While the literature shows that physical activity decreases with age, frequently used variables are habitual activity, moderate to vigorous physical activity, or vigorous physical activity. BMI, sum of skinfold thickness, and waist circumference, but not BMI z score, have been frequently used in obesity research. Although each sedentary behavior (TV, video games, computer use) seems to have different characteristics, many researchers have used a combined hours of sedentary behaviors. Therefore, using different indicators for physical activity, sedentary behaviors, and obesity will make it possible to understand the whole picture of complicated relationships between health behaviors and obesity.

Another crucial issue is the inter-relationship and possible interaction between physical activity and sedentary behaviors with obesity. Knowing the inter-relationship is important for developing obesity intervention programs. If physical activity and sedentary behaviors are negatively related, this would indicate that highly active children spend less time in sedentary behaviors. Thus, a comparison of odds ratios (or magnitude of influence on obesity) from the two risk factors can help us understand the relative importance on obesity, and, consequently, help guide the choice of behavior selected as a target behavior. In contrast, if physical activity and sedentary behaviors are not related, this would indicate that two different dimensions exist in activity, which means individuals can be active and sedentary at the same time. Hence, intervention programs focusing only one behavior may not be effective for all subjects because children can have significant amounts of both active and sedentary behaviors. In this case, it is critical to investigate interaction effects between physical activity and sedentary behaviors and obesity. Currently no information can be found about interaction effects between physical activity and sedentary behaviors and obesity.

CHAPTER 3

METHODOLOGY

This was a secondary data analysis of the CHIC (Cardiovascular Health in Children and Youth) study. Using longitudinal data of physical activity, sedentary behaviors, and childhood obesity in elementary to high school students from rural North Carolina, the current study examined: (a) trajectories of physical activity, sedentary behaviors and obesity throughout maturation (age); (b) how child characteristics and parental characteristics influenced physical activity and sedentary behaviors across age; (c) the extent of obesity explained by physical activity and sedentary behaviors across age; and (d) whether there was an interaction between physical activity, sedentary behaviors, and obesity across age. Child characteristics (age, puberty, gender, and race), child dietary behavior (intake of sweet drinks), and parental characteristics (family income, parental education, physical activity, and obesity) were included in the analyses.

This chapter includes a description of the original CHIC study, setting and sampling, procedures, variables and measures, and methods of data analysis for the current study.

A Description of the CHIC Study

The Cardiovascular Health in Children and Youth (CHIC) study (PI: Joanne Harrell) investigated the effects of school-based intervention programs for cardiovascular health promotion in North Carolina youth. CHIC I & II also described the development of cardiovascular risk and obesity throughout childhood and adolescence (Harrell and Frauman, 1994; McMurray et al., 2000). CHIC III was a descriptive study that examined the development of the MS from children and adolescents.

The CHIC study is a longitudinal study that had three phases (Figure 3.1). The first phase, CHIC I, included an 8-week, randomized, controlled, school based-intervention program in 1990 in 18 urban and rural elementary schools chosen from 125 schools in North Carolina (NC). About 2,200 third and fourth graders were initially post-tested in 1991 (n=2,045) and followed up in 1992 (n=1,829).

The second phase, CHIC II, which had two major aims, began in 1994. The first aim was to examine the longitudinal effects of the CHIC I intervention. Data were collected in the sample of CHIC I subjects and 463 additional urban and rural control subjects in 1994 to 1997. The second aim was to investigate the effects of a cardiovascular risk prevention program in middle schools. Five rural middle schools participated in an 8-week intervention program in schools from different counties in NC, where students were not exposed to the CHIC I intervention. The pre-test and the intervention were conducted in fall of 1995. Post-tests were done in spring of 1996 and spring of 1997.

Unlike CHIC I, the setting for the CHIC II intervention program was only in rural NC. Schools in rural areas were chosen based on results from CHIC I that the prevalence of obesity in rural North Carolina children was higher than in their urban counterparts (Harrell & Frauman, 1994; McMurray, Harrell, Bangdiwala, & Deng, 1999). That is, when obesity was defined as higher than 90^{th} age-specific BMI percentile, the prevalence of obesity in rural black children (33.5%) was higher than in any other children including rural white

(28.5%), urban black (22.2%), and urban white children (21.7%).

Figure 3.1 Timeline of CHIC Study

Phase	Year	Cohort	The current study
**CHIC I Elementary school	1990	Cohort 1, pre-test (3rd & 4th)	X (1990–1992)
	1991	Cohort 1, post 1 (3rd & 4th)	
	1992	Cohort 1, post 2 (4th & 5th)	
	1993		
**CHIC II Middle school (cohort2: only control group)	1994	Cohort 1&2, post 3 (6th & 7th)	**O** (rural)
	1995	Cohort 1&2, post 4 (7th & 8th)	**O** (rural)
		Cohort 3, pre-test (6th – 8th)	**X**
	1996	Cohort 1&2, post 5 (8th & 9th)	**O** (rural)
		Cohort 3, post 1 (6th - 8th)	**X**
	1997	Cohort 1&2, post 6 (9th &10th)	**O** (rural)
		Cohort 3, post 2 (7th - 9th)	**O**
	1998		
	1999		
*CHIC III High school: cohort 4 Elementary school: cohort 5	2000	Cohort 3, post 4 (10th – 12th)	**O** (2000–2003)
		Cohort 4 ,time1 (9th – 11th)	
		Cohort 5 time 1 (3rd – 5th)	
	2001	Cohort 3, post 5 (11th & 12th)	
		Cohort 4, time 2 (10th – 12th)	
		Cohort 5, time 2 (4th – 6th)	
	2002	Cohort 3, post 6 (12th)	
		Cohort 4, time 3 (11th & 12th)	
		Cohort 5, time 3 (5th – 7th)	
	2003	Cohort 4, time 4 (12th)	

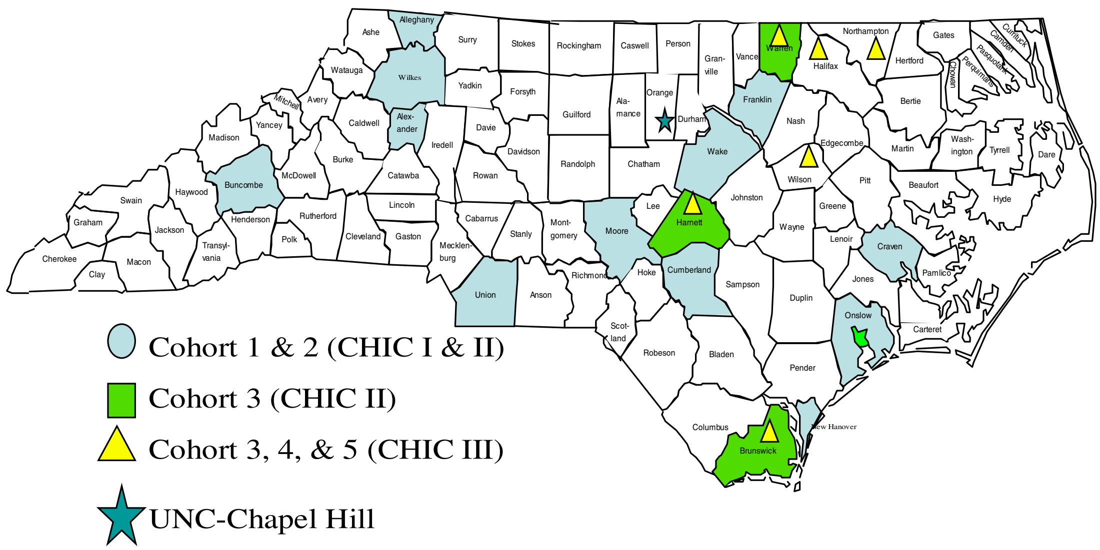
Intervention/control group **   **O** Included in this study
Descriptive study *   **X** Not included in this study

The third phase, CHIC III, was a longitudinal descriptive study conducted in rural elementary and high schools to investigate the development of cardiovascular disease risk factors, in particular, the metabolic syndrome, throughout puberty. Observations were made in 2000, 2001, 2002 and 2003. Black children and adolescents were intentionally over-sampled. About 1,500 elementary school students and 670 high school students were newly recruited in 2000, and approximately 180 subjects from CHIC II were also observed.

The CHIC study was composed of 5 cohorts. Cohort 1 was elementary school students for the intervention trial in the CHIC I phase. Cohort 2 was an additional control group that included students from the same grade as ones in cohort 1. Cohort 3 was constructed for the intervention study in middle schools in the CHIC II phase and those subjects were followed for the subsequent descriptive study (CHIC III). In addition, CHIC III was composed of cohort 4 (high school cohort) and cohort 5 (elementary school cohort). Both cohort 4 and 5 were recruited for the descriptive study.

One of challenges of a longitudinal study is to maintain retention of subjects. Diverse approaches were used. Each school received summary reports about the cardiovascular health status of its students compared to other schools. Frequent contacts were also made with school personnel. Summary reports about their child's heart health status including laboratory test results were sent to parents after each data collecting period. Small tokens including cash or gift certificates and holiday cards were provided to children who completed data collection. Most loss of students was due to moving, graduation, or being absent on the days of data collection at the school.

Figure 3.2 North Carolina Counties Participating in CHIC



Setting and Sampling

Setting

The setting of the CHIC I (cohort 1) was urban and rural elementary, middle, and high schools from 12 counties in NC (Figure 3.2). The additional control group subjects were added in CHIC II (cohort 2). Five middle schools from 4 rural counties were added in CHIC II intervention study (cohort 3). The setting of CHIC III (cohorts 4 & 5) was 27 elementary and 7 high schools from 4 counties in NC, including Halifax, North Hampton, Warren, and Wilson counties. The population of those counties was at least 50% African American.

The current study includes rural, black and white subjects. Selecting only rural subjects, regardless of intervention or control group, was based on following reasons. First, CHIC II included rural and urban subjects but the setting of CHIC III was only rural. As noted above, rural subjects were more obese than the urban children in CHIC I (Harrell &

Frauman,1994; McMurray et al., 1999). Thus, urban subjects were eliminated to prevent confounding by urban and rural settings. Second, the intervention programs were provided in previous years. For cohort 1, the intervention was provided in 1990 and observations included in this study are from 1994. For cohort 3, the intervention was provided in 1995 and observations included are from 1997. In addition, those programs were relatively short (8-week program) and no booster program was provided. The intervention effects were likely to fade away due to the time difference between intervention and observations included in this study. Only white and black subjects were included as number of subjects of other races was less than 10%.

Sampling Criteria for the CHIC I, II, & III Studies

The inclusion criteria for the CHIC studies were as follows: (a) were able to read and write English; (b) had no mental, emotional, or physical handicap reported by parents, teachers, or school nurse; (c) had no chronic illness affecting the measurement of variables, such as diabetes, serious renal disease, or moderate to severe asthma reported by parents, teachers, school nurse, or child; (d) had at least one natural parent who could answer about family history; (e) were able to ride the cycle ergometer; and (f) had written parental consent and their assent.

In addition to the above noted criteria, CHIC II subjects were those who participated in the CHIC I study, or new control subjects in the same grade, that is, 6th to 10th graders aged 11 to 17. CHIC III subjects were initially aged 14-18 and in 9th – 11th grades or initially aged 8-12 and in 3rd -5th grades.

Procedure

The CHIC study was approved by the Institutional Review Board for the Protection of Human Subjects of the University of North Carolina at Chapel Hill, School of Nursing. Approval from school principals and school district superintendents was also obtained.

As for recruitment of the middle school cohort (CHIC II), a packet was mailed to the parents of continuing students from CHIC I and to the parents of the additional control group subjects who were newly recruited from schools. The packet included a cover letter explaining the study, a consent form, and the parental questionnaire. Parents were also informed that they would receive results of health assessment of their children as an incentive for participation and that their children would also be provided a small incentive ($ 20). A stamped envelope was included for returning the parental questionnaires and the signed consent form. Two weeks after the packet was mailed, a reminder postcard was sent to parents to thank them for returning the forms if they had done so, or to persuade them to return the forms.

To increase participation rate, a letter of support from school principals was included in the initial packet for parents. Extra packets were available at school sites for students who wanted to participate in the study when the data collection was conducted.

Data Collection

All data were collected at the school sites in school gyms, media rooms, or empty classrooms. Fasting venipuncture was done at their school, early in the morning before class started. Other data were collected during health, physical education or elective classes. Physiologic data, including height, weight, skinfold thickness, blood pressure (BP), and aerobic capacity were measured. Height, weight, and BP were measured twice, and skinfold thickness three times. In addition, for inter-rater reliability, different RAs remeasured the above data in 1 out of 10 subjects. RAs were trained appropriately before data collection and tested for inter-reliability.

Self-report questionnaires were answered in small groups with RA's supervision. The Youth Health Survey (YHS) was filled out while subjects were waiting for venipuncture. The Pubertal Development Scale (PDS) was administered in a secluded area for privacy.

Variables and Measures

The Youth Health Survey (YHS) and Eating Habit Questionnaire (EHQ) were used to measure health behaviors at multiple time points. The YHS was developed to assess health behaviors including habitual physical activity, sedentary behaviors, smoking habits, etc (Gilmer, Speck, Bradley, Harrell, & Belyea, 1996). The Habitual Physical Activity subscale of the YHS was used to measure physical activity. Additional questions about time spent in front of the TV, video game play, and computer use were in the YHS, but were not part of the Habitual Physical Activity subscale used to measure sedentary behaviors. Diet behavior (intake of sweet drinks) was measured using the Eating Habits Questionnaire (EHQ). The Mothers Questionnaire and the Fathers Questionnaire were used to measure parental characteristics, such as family income, parental education, self-reported height and weight, and activity level (Appendix L). Each subjects had maximum 3 or 4 observations according to cohort

As Menard (2002) mentioned a possibility of missing for one or more items of scale or for an entire scale in a certain time point in longitudinal data, some data were not available at certain time points or cohorts in CHIC (Table 3.1 and 3.2). That is, questions about sedentary behaviors, including TV, video, and computer use, were not included in elementary school version of the YHS (cohort 5). An item about computer use, one of sedentary behavior questions, was not included in cohort 1 & 2 and cohort 3 post 2. In addition, data about diet behavior (intake of sweet drinks) and waist circumference were not included in cohort 1 & 2 and cohort 3 post 2.

Table 3.1

Variables and Measures

Construct	Concepts	Instrument	Variables
Health Behaviors	Physical Activity	Youth Health Survey (Subset: Habitual Physical Activity)	- Total activity score - Low PA score - Moderate PA score - Vigorous PA score
	Sedentary Behaviors	YHS	- Hours of TV viewing * - Hours of video games * - Hours of computer use +
	Diet Behavior	Eating Habit Questionnaire	- Frequency of sweet drink intake**
Health Outcome	Overweight Obesity	Physiological Data Sheet (height, weight, SSF, and waist)	- BMI - BMI z - SSF - Waist circumference**
Child Characteristics	Developmental Level	Pubertal Development Scale	- Pubertal status
		Physiological Data Sheet	- Age
	Gender		- Gender
	Race	YHS	- Race
Parental Characteristics	Parental SES	Mothers & Fathers Questionnaire	- Education years - Family income
	Parental Obesity		- BMI
	Parental Activity		- Frequency of participation in 20-30 min PA

Note. ** only available in cohort 3, 4, & 5, * only available in cohort 1& 2, 3, 4
+ only available in cohort 3 & 4

Table 3.2

Missing Data by Cohort and Time Points

	Cohort 1 & 2 (middle school)	Cohort 3 (mid+high school)	Cohort 4 (high school)	Cohort 5 (elementary school)
Time points	*P3	*P2	T1	**T1
	*P4	P4	T2	**T2
	*P5	P5	T3	**T3
	*P6	P6	T4	

Note. * no data for hours of computer use, eating behavior, waist circumference
** no data for hours of sedentary behaviors (TV, video game, and computer use)

Health Behavior: Physical Activity

As mentioned above, activity level was determined by a self-report questionnaire, the Habitual Physical Activity subscale of the Youth Health Survey (YHS). Subjects were asked how often certain activities were done for more than 15 minutes during the past week. A pilot study of 205, 6th to 8th graders showed that the Habitual Activity subscale of YHS (29 items) had a coefficient alpha of 0.74 and a correlation of 0.70 for 2-week test-retest (Gilmer et al., 1996).

The specific activities listed in the YHS were slightly different among different cohorts and time points (Appendix A, B, & C). For the comparison between different cohorts and time points, the same common 27 activities were used for creating physical activity variables (Table 3.3). In the middle and the high school cohorts, each activity was answered by “0,” “1-2 times,” “3-5 times,” and “6 or more.” Options for elementary school cohort (cohort 5) were “none,” “not much,”, “sometimes,” and “a lot” to make it easier for elementary school students to answer. Because the scales were different, the frequency was weighted as shown at Table 3.4.

Table 3.3

MET Score for the Habitual Physical Activity

#	Activities	Weights (METS)	Intensity
1	Aerobics or cheerleading	5	Moderate
2	Arts and crafts	2	Low
3	Baseball or softball	5	Moderate
4	Basketball	8	Vigorous
5	Bicycling	5	Moderate
6	Bowling	3	Low
7	Collecting (stamps,rocks, etc)	2	Low
8	Dancing	5	Moderate
9	Football	8	Vigorous
10	Group meetings or club meetings	2	Low
11	Gym class (PE)	5	Moderate
12	Gymnastics	3	Low
13	Homework	2	Low
14	Jumping Rope	8	Vigorous
15	Karate or Judo	5	Moderate
16	Music Lessons	3	Low
17	Reading	2	Low
18	Roller-skating or In-line skating	8	Vigorous
19	Running	8	Vigorous
20	Soccer	8	Vigorous
21	Skate Boarding	5	Moderate
22	Swimming	8	Vigorous
23	Tennis	8	Vigorous
24	Television of VCR movies	2	Low
25	Video games	3	Low
26	Walking	3	Low
27	Yardwork or Farmwork	5	Moderate

Table 3.4

Weighted Frequency of Activities per Week

Middle and High School Form	Elementary School Form	Weighted Frequency
0	None	0
1-2 times	Not much	1.5
3-5 times	Sometimes	4
6 or more	A lot	6

Activity score (MET*session/week) was calculated by multiplying the reported frequency of each activity by the assigned MET score for that activity. MET scores were assigned by two exercise physiology experts based on the compendium of physical activity developed by Ainsworth et al. (2000) (Harrell et al., 1997; McMurray, Harrell, Bangdiwala, & Hu, 2003). Each activity was assigned as 2, 3, 5, or 8 METs (low level PA: 2 or 3, moderate PA: 5, and vigorous PA: 8 METs).

To evaluate different aspects of physical activity (PA), four different variables, derived from the Habitual Physical Activity subscale of the YHS, were used in analyses: (a) total activity score, (b) low PA score, (c) moderate PA score, and (d) vigorous PA score.

Total physical activity score (Total PA).

Total activity score is a summed value of all 27 activity scores (Table 3.5). To obtain the activity score, frequency was be coded using 0, 1.5, 4, and 6 of weights to make it possible to compare the 2 different methods of determining frequency (table 3.4). Then, the weighted frequency of each activity was multiplied by the MET score, assigned by the experts. Finally, 27 activity scores were summed. A possible range (20-580 MET*session/week) was suggested by one of the co-investigators of CHIC (RGM).

Low PA score (LPA).

Low intensity PA score is a subset of the total activity score. Low level intensity of physical activity (LPA) was defined as activities of 2 or 3 METs, such as, arts and crafts, bowling, and collecting, etc (Table 3.3). To calculate low PA score, 11 activities assigned 2 or 3 METs were multiplied with the weighted frequency reported, and then summed. A range of LPA was 0 to 158 MET*session/week.

Table 3.5

An Example of Scoring Physical Activity Indicators

	TIMES THIS PAST WEEK						
					Weighted frequency	MET	+Activity score
Aerobics or cheerleading	0	1 – 2	3 – 5	6+	1.5	5 (M)	7.5 **
Arts and crafts (draw, paint)	0	1 – 2	3 – 5	6+	0	2 (L)	0 *
Baseball or softball	0	1 – 2	3 – 5	6+	6	5 (M)	30 **
Basketball	0	1 – 2	3 – 5	6+	1.5	8 (V)	12 ***
Bicycling	0	1 – 2	3 – 5	6+	0	5 (M)	0 **
Bowling	0	1 – 2	3 – 5	6+	4	3 (L)	12 *
Collecting (stamps, rocks, cards)	0	1 – 2	3 – 5	6+	1.5	2 (L)	3 *
Dancing	0	1 – 2	3 – 5	6+	4	5 (M)	20 **
Football	0	1 – 2	3 – 5	6+	0	8 (V)	0 ***
Group meetings or club meetings	0	1 – 2	3 – 5	6+	1.5	2 (L)	3 *
Gym class (PE)	0	1 – 2	3 – 5	6+	1.5	5 (M)	7.5 **
Gymnastics	0	1 – 2	3 – 5	6+	0	3 (L)	0 *
Homework	0	1 – 2	3 – 5	6+	4	2 (L)	8 *
Jumping Rope	0	1 – 2	3 – 5	6+	0	8 (V)	0 ***
Karate or Judo	0	1 – 2	3 – 5	6+	0	5 (M)	0 **
Music Lessons (choir, band)	0	1 – 2	3 – 5	6+	0	3 (L)	0 *
Reading	0	1 – 2	3 – 5	6+	4	2 (L)	8 *
Roller-skating or In-line skating	0	1 – 2	3 – 5	6+	0	8 (V)	0 ***
Running	0	1 – 2	3 – 5	6+	0	8 (V)	0 ***
Soccer	0	1 – 2	3 - 5	6+	0	8 (V)	0 ***
Skate Boarding	0	1 – 2	3 - 5	6+	0	5 (M)	0 **
Swimming	0	1 – 2	3 - 5	6+	1.5	8 (V)	12 ***
Tennis	0	1 – 2	3 – 5	6+	1.5	8 (V)	12 ***
Television or VCR movies	0	1 – 2	3 – 5	6+	4	2 (L)	8 *
Video Games	0	1 – 2	3 – 5	6+	4	3 (L)	12 *
Walking	0	1 – 2	3 – 5	6+	4	3 (L)	12 *
Yardwork or Farmwork	0	1 – 2	3 – 5	6+	0	5 (M)	0 **

Note. (L): low intensity, (M): moderate intensity, and (V): vigorous intensity
+Activity score = weighted frequency x MET
Low PA score = sum of activity scores for 11 low intensity PA (*) = 64
Moderate PA score = sum of activity scores for 8 moderate PA (**) = 65
Vigorous PA score = sum of activity scores for 8 vigorous PA (***) = 36
Total PA score = sum of 27 activity scores = 165

Moderate PA score (MPA).

Moderate PA score is also a subset of the total activity score. Moderate PA was defined as activities of 5 METs. Eight items, such as aerobics or cheerleading, baseball or softball, bicycling, etc, were assigned as 5 METs. Each item was multiplied with weighted frequency and the multiplied values were summed. A range of MPA was 0 to 200 MET*session/week.

Vigorous PA score (VPA).

Vigorous PA is another subset score. Vigorous PA was defined as activities of 8 METs. Eight activities, such as basketball, football, and jumping rope, were assigned with a MET level of 8. The MET score was multiplied by the weighted frequency of these 8 items. The 8 multiplied activity scores were summed. A range of VPA was 0 to 348 MET*session/week.

Health Behavior: Sedentary Behaviors

Questions for the measurement of sedentary behaviors were also from the YHS but were in addition to the 27 questions of the Habitual Physical Activity subscale. Sedentary behaviors were measured by asking time spent in TV viewing, video games, and computer use (Appendix D & E). Three variables are to be used in analyses: hours of (a) TV viewing per week, (b) video game per week, and (c) computer use per week.

Hours of TV viewing per week.

Time spent in TV viewing was asked by the question, "Currently, how long each day do you usually watch TV?" The answer was chosen between "never," "less than 1 hour," "1 to less than 2 hours," "2 to less than 3 hours," and "3 or more hours." Time in front of the TV during school days and non-school days were reported separately. Data from both school days and non-school days was used to calculate TV viewing hours per week (Table 3.6). First, total time spent in TV watching during school days was determined by multiplying 5 (days) with 0, 0.5, 1.5, 2.5, and 3.5 of weighted time, which corresponded to never, less than 1 hour, 1 to less than 2 hours, 2 to less than 3 hours, and 3 or more hours (table 3.6). Then, total hours of TV viewing during non-school days was also be calculated by multiplying 2 (days) with the same weighted time above. Thus, the hours of TV viewing per week were a summed score of TV viewing hours during school days and non-school days. Possible range of hours of TV viewing per week was 0 to 24.5 hours.

Hours of video game play per week.

A similar question was used for the measurement, which is "Currently, how long each day do you usually play video games?" The options for an answer of this item were the same as TV viewing. Hours of video game per week were obtained with the same method as hours of TV viewing per week. Possible range of hours of video game play per week was 0 to 24.5 hours.

Table 3.6

Weighted Hours for Sedentary Behaviors per Week

School days	(Weighted hours) x 5 school days	Non-school days	(Weighted hours) x 2 non-school days
Never	(0) x 5 = 0	Never	(0) x 2 = 0
Less than 1 hours	(0.5) x 5 =2.5	Less than 1 hours	(0.5) x 2 = 1
1 to less than 2 hours	(1.5) x 5 =7.5	1 to less than 2 hours	(1.5) x 2 = 3
2 less than 3 hours	(2.5) x 5 =12.5	2 less than 3 hours	(2.5) x 2 = 5
3 or more hours	(3.5) x 5 =17.5	3 or more hours	(3.5) x 2 = 7

Hours of computer use per week.

The item for computer use was added in CHIC III. The question was that “Other than for homework and video games, currently how much time each day do you usually spend on the computer?” The answering scheme was the same as above. Hours of computer use per week were also be calculated as the same method as hours of TV viewing per week. Possible range of hours of computer use per week was also 0 to 24.5 hours.

Health Behavior: Eating Behavior

In the middle and high school cohorts (CHIC III), eating behavior was measured by the Eating Habits Questionnaire (EHQ), which includes 8 food groups. The subjects were asked how many times they ate a certain food during the past week. Reliability and validity was examined in 446 middle school students. Internal consistency was 0.60 to 0.89 and test-retest reliability was 0.46 to 0.85 (Speck, Bradley, Harrell, & Belyea, 2001). The eating behavior questionnaire used in CHIC II did not include questions on intake of sweet drinks.

In elementary school children in CHIC III, the EHQ was applied in small group settings where a trained RA read items in EHQ to children and answered questions asked by students. The font size was larger than the high school form but the content was the same.

Frequency of sweet drinks per day.

Daily serving frequency of sweet drinks will be used for the eating behavior variable. Daily intake frequency was calculated by summing frequencies of drinking regular soda, fruit flavored soda, Kool-aid, etc. The instruction was “For each food item listed below, mark an “X” in the column which best describe how often you ate that food last week.” For sweet drinks, the choices were (a) regular or caffeine free regular soda (Coke, Pepsi, 7-up, Root

Beer, etc), (b) fruit flavored soda (Sunkist Orange, Welch's Grape, Cherry, etc), and (c) Kool-Aid, Hawaiian Punch, Hi-C, Tropicana Twisters.

Table 3.7

Weights of Sweet Drink Intake

Middle and High school form						
Frequency	3 or more time a day	1-2 times a day	3-6 time last week	1-2 times last week	Not last week	Never
Weights	21	10.5	4.5	1.5	0	0
Elementary school form						
Frequency	Every day (7)	Almost every day (5-6)	Some times (3-4)	Not many (1-2)	Not last week (0)	Never eat it
Weights	10.5	5.5	3.5	1.5	0	0

The options for frequency of the items differed by cohorts. Middle and high school cohorts answered "3 or more times a day," "1-2 times a day," "3-6 times last week," "1-2 times last week," "not last week," and "never drink it." For the elementary students, the choices were "everyday (7)," "almost everyday (5-6)," "some times (3-4)," "not many (1-2)," "not last week (0)," and "never eat it (0)." Weighted frequency was used to obtain daily serving frequency of sweet drink. The procedure to obtain the variable is as follows. First, 21, 10.5, 4.5, 1.5, 0, and 0 of weekly serving frequency were used for middle and high school cohorts (Table 3.7). For elementary school cohort, 10.5, 5.5, 3.5, 1.5, 0, and 0 were used as frequency weights. Then, weekly serving frequency was divided by 7 to calculate daily frequency.

Child Health Outcome: Obesity and Overweight

BMI.

BMI was calculated as body mass (weight in kilograms) divided by squared height (meters). Height and weight were measured twice. Height was measured to the nearest 0.1 cm on a stadiometer (Kalamzoo, MI), shoeless, with the head horizontal in the Frankfort plane and heels against the stadiometer. Weight was measured to the nearest 0.1 kg using an electric ProPlus metric scale (Healthometer Medical, Bridgeview, IL) under the shoeless status while clothed. The scale was calibrated using standardized weights before use at each school.

BMI z score.

BMI z score is a standard deviation score using the distribution of referent populations. For instance, BMI z score of 1 or 2 means that the BMI of an individual is one or two standard deviations above the mean or the median value of the age and gender specific reference value. The CDC growth chart (2000) by age and gender was used for the standardization. SAS programs on the CDC website were used for the calculation of BMI z score (http://www.cdc.gov/nccdphp/dnpa/growthcharts/sas.htm).

Sum of skinfold thickness (SSF).

Sum of skinfold thickness (SSF) was calculated from the summation of triceps and subscupular skinfold thickness. Both were measured three times and the average value was used. Lange skinfold calipers, which provided a pressure of 10 g/mm^2, were employed for the measurement. The measurement site of triceps was determined with a tape to locate the midpoint between the acromion and the olecranon processes when elbow was bent 90 degree.

Diagonally 1 cm below the inferior angle of the scapular was the location of subscapular thickness measurement.

Waist circumference.

Waist circumference was measured twice. Two RAs were required to measure. One stood in front of the subject and the other stood behind the subject to make sure that the tape around the subject was horizontal. The location of waist circumference was just above the iliac crest at the midpoint of the axillary line, which was the same method used in NHANES III protocol (National Institutes of Health, 1998). Measurement was made to the nearest 1mm.

Child Characteristics

Pubertal stage.

Pubertal stage was determined by self-reported questionnaire, the Pubertal Development Scale (PDS, Petersen, Crockett, Richards, & Boxer, 1988). To decide the pubertal stage, the growth of underarm and public hair, the development of breast, and menstruation were considered for girls (Appendix J). The change of voice, growth of underarm and pubic hair, and face hair were used for boys (Appendix K). Questions were answered by an ordinal scale: 1 (not started), 2 (barely started), 3 (definitely underway), and 4 (seems completed). A question on menarche was responded by yes or no and scored 4 for yes and 1 for no. The pubertal status was decided on the basis of the summed score (Figure 3.3). Pubertal stage was coded as 1 (prepuberty) to 5 (post puberty).

Reliability of the scale has been reported in previous research studies. Goodman et al. (1998) reported the internal consistency for boys and girls was .81 and .82, respectively, and Siegel et al. (1999) presented .75 for the internal consistency for boys and girls.

Figure 3.3 Scoring Pubertal Status from the PDS

Girls		Boys	Pubertal status
Menarche= 1 →	0 < Breast & body hair score < 3	0 < Voice, body & face hair score < 4	1
(Menarche= 1) →	3 ≤ Breast & body hair score < 4	4 ≤ Voice, body & face hair score <6	2
(Menarche= 1) →	4 ≤ Breast & body hair score ≤ 8	6 ≤ Voice, body & face hair score < 9	3
Menarche= 4 →	Breast & body hair score ≤ 7	9 ≤ Voice, body & face hair score ≤ 11	4
(Menarche= 4) →	Breast & body hair score = 8	Voice, body & face hair score = 12	5

Age, gender, and race.

Information about age and gender were collected from children by self-report. The data was verified with school records. Age for this study was calculated with the difference between date of birth and date of data collection. Thus, age was included as a continuous variable in analyses. If subjects had no information about birth date but truncated age, then age was replaced with a truncated age plus 0.5 of year. For instance, truncated age of 14 was entered as 14.5 years of age.

As for gender, boys were coded as “M” and girls as “F.” Race was determined by self-reported data and verified using the process of longitudinal comparison and school records. Black was coded as “B” and White as “W.”

Parental Characteristics

Parental socioeconomic status (SES).

Total family income and parental education were used for measuring parental socioeconomic status (SES). Total family income was asked by the question, "What is your total family income?," and possible responses were less than $5000, $5000-$9,999, $10,000-$19,999, $20,000-$29,999, $30,000-$39,999, $40,000-$49,999, $50,000-$74,999, $75,000-$100,000, and above $100,000. The income level was categorized and coded as 1 (- $19,999), 2 ($ 20,000-39,999), 3($ 40,000-74,999), and 4 ($ 75,000-). Family income reported by fathers was used to create parental SES variable. If there was no data of fathers available, then reports from mothers were used.

Parental education was another SES variable. It was asked by the question, "What is the highest grade you finished?" and answered with "sixth grade or less," "junior high (7th - 9th grade)," "some high school (10th or 11th grade)," "high school graduate," "some college or specialized training," "college or university graduate," "graduate professional training (graduate degree)." The higher education from either father or mother was used to create a variable. Parental education level was categorized into 1 (less than high school), 2 (high school graduate), 3 (some college or specialized training), and 4 (college or more).

Parental obesity.

Parental obesity, which is a categorical BMI risk, was obtained using self-reported height and weight. The questions for height and weight were "How tall are you?," (in feet and inches) and "How much do you weigh?" (in pounds). BMI was calculated in weight in kilograms divided by squared height in meters after converting feet and inches into kilograms and meters. Greater BMI from either father or mother was used. It was categorized into 1 (less than 25), 2 (equal to 25 to less than 30), 3 (equal to 30 to less than 35) and 4 (equal to 35 or greater).

Parental physical activity.

The level of parental activity was asked using the question, "In the last 6 months, about how often did you participate in one or more physical activities that lasted 20-30 minutes?" It was answered with "not at all," "less than once a month," "about once a month," "2-3 times a month," "1-2 times a week," and "3 or more times a week." Higher activity level reported by either father or mother was used for this categorical variable and coded as 1 (~ less than 1 time/month), 2 (1-3 times/month), 3 (1-2 time/week), and 4 (3 or more times a week).

Preparation of Data for Analysis

Data cleaning was conducted before answering the research questions. Any height greater than 3 SD beyond age- and gender- specific mean height was verified with a comparison of repeatedly measured height (longitudinal comparison). If high all time points, then height data of the subject was included. Otherwise the height was set to missing (0 subjects detected). Any subjects who declined in height more than 1 inch between subsequent measures (about 1 year apart) were set to missing (data from 17 subjects). Any subsequent height change greater than 3 SD beyond age- and gender- specific mean change was verified with a comparison of repeatedly measured height (0 subjects detected). After computing BMI, subjects who had greater than 3 SD beyond the age- and gender-specific mean BMI or who had a BMI less than 12 (biological limit-clinical opinion) were verified. Any subsequent BMI change greater than 3 SD beyond age- and gender- specific mean BMI change was also verified with a longitudinal comparison (data from 6 subjects set to missing). BMI z score, SSF, and waist circumference were also verified with the same method (data from additional 8 subjects set to missing).

For the physical activity score, data from subjects who had more than 25% missing, which corresponded to 7 or more items, were set to missing (data from less than 40 subjects was set to missing at each time point). Sedentary behaviors were checked for patterns and set to missing if subjects answered that they spent 3 or more hours each in TV viewing, video game, computer use, and homework daily (date from 9 subjects set to missing) for the lack of plausibility. Mother and father whose height or BMI was greater than 3 SD beyond gender specific mean were set to missing (data from 39 subjects set to missing).

Methods of Analysis

Descriptive statistics, such as mean and standard deviation of continuous variables, and frequency and percentage of dichotomous variables, were provided. Inter-correlations between repeated measures of major variables were also presented. The SAS program (version: 9.1.3) was used for analyses. A mixed effect model, which can account for correlations of clustered data and repeated measures, was used to answer research questions.

A Mixed Effect Model

A mixed effect model (Individual Growth Curve Model) was the method used to answer the research questions. Unlike standard regression model, a mixed effects model is a statistical method that can handle correlated observation data (Twisk, 2003). A standard regression model approach assumes that a continuous outcome variable Y can be explained by one or more predictor variables of X (equation 1).

$$Y= X\beta + e \quad \text{(Equation 1)},$$

where Y is an outcome variable for a subject, X is an independent variable for a subject, β is a regression coefficient for independent variable X, and e is an error for a subject (Campbell, Grimshaw, & Elbourne, 2004). The error term (e) is assumed to be independent and to vary randomly. That is, the error term follows normal distribution with mean of 0 [N $(0, \sigma^2)$]. In other words, Y can be explained by the relationship with a vector of independent variable X through a linear function with unknown fixed parameters β and the non-explained variability of Y contained in the vector of independent errors (e), or, a random portion.

Longitudinal data or clustered data violate the above mentioned independence assumption of error variance, because observations within a subject are correlated over time or because subjects within a cluster have some correlation among their values. Thus, a mixed effect modeling approach is to decompose the random portion (error term) of equation (1) by modeling random effects in addition to the fixed effects β. Thus, for a mixed effect model, equation (1) became equation (2) as follow:

$$Y= X\beta + Z\gamma + e^* \text{ (Equation 2)},$$

where $X\beta$ remains as the fixed components of the model and $Z\gamma + e^*$ is the new random components of the model(Singer, 1998). For longitudinal data, a typical Z covariate would be each subject. In other words, an effect of subject (correlation over time) accounts for part of the variability of Y. However, this subject effect is considered as random for 2 reasons. First, subjects are a sample of all possible subjects and second, each individual subject effect is not the research interest. Thus, subject effect is to be adjusted in the model.

Suppose that each subject has repeatedly measured observations. Equation (2) can be written as equation (3), which adjusted correlation between repeated measures of each subject.

$$Y = \beta_0 + X\beta^* + Z\gamma^* + e^{**} \text{ (Equation 3)},$$

where $\beta_0 + X\beta^*$ is a fixed effect (β_0: intercept of population) and $Z\gamma^* + e^*$ is a random effect. Or, equation (2) can be written as equation (4) in which it has random intercepts for each cluster (school district, β_{0s}).

$$Y = \beta_0 + X\beta^* + \beta_{0s} + Z\gamma^{**} + e^{***} \text{ (Equation 4)}$$

The model could be more complicated by allowing each subject or school to have a different slope for a particular residual, but this adds too many additional parameters to be estimated. Thus, equation (4) will be the model for the current study.

The current study included 2 levels of correlation (intra-class correlation, ICC): intra-school district correlation and intra-individual correlation. Intra-class correlation means how similar subjects within a cluster (class) are (Singer, 1998). Thus, intra-school district correlation represents the similarity of observations of subjects within a school district. Intra-individual correlation indicates the similarity of repeatedly measured observations of individuals. For instance, suppose that there are 5 students in each of 5 schools. If ICC (intra-school correlation) for a certain variable is 1, then subjects within a school district (cluster) all have the same information for that variable. If ICC is 0 for another variable, then observations of students in the school district are independent. Likewise, ICC of 1 for intra-individual correlation means that repeatedly observed outcomes of a certain individual all have the same information. These 2 levels of correlation are to be included in statistical models to be tested, because clustered sampling method (unit of cluster: school district) and repeated measures of individuals were used for the CHIC study.

The correlation of observations over time or the correlation of observations within a cluster is accounted for in models through the covariance structure (Singer, 1998; Twisk, 2003). Thus, a mixed effect model assumes that the covariance structure is correctly specified. The structure of the covariance matrix can be compound symmetry, autoregressive, unstructured, etc. The current study fitted models repeatedly using compound symmetry (CS), autoregressive (AR (1)), and unstructured (UN) covariance structure. Then, fit statistics was compared to choose the best fit model, that is, the one with the smallest fit indexes (AIC, BIC, and AICC). In particular, smaller BIC (Bayesian information criterion) was used for the criterion for model selection. BIC can be calculated as follow:

$$BIC = \log (L) - [0.5 \times \log (n) \times (k)],$$

where L is a value of the model's maximized likelihood, n is a sample size, and k is a number of parameters . Thus, smaller BIC means a more parsimonious model (Burnham & Anderson, 2004; Littel, Milliken, Stroup, & Wolfinger, 1996; Twisk, 2003). In results, UN was the most appropriate covariance structure in that models with UN had the smallest BIC. The results shown in this paper were from models with UN.

A mixed effect model also requires assumptions of multivariate normality (univatiate normality and bivariate normality) and normal distribution of a random effect (normal distribution of random slope and random intercept) (Twisk, 2003). Another assumption is related to missing data. The model requires the assumption of missing at random (Twisk, 2004). Thus, residual analysis as a diagnostics of models was performed as model diagnostics.

Random Effects: Intra-School District and Intra-Individual Correlations

Correlation of subjects within the same school district (intra-school district correlation) was adjusted as a random effect. Since data were collected from clustered sampling (unit of cluster: school), similarities of students within the same school may exist. Hence, correlation of subjects within the same school (intra-school correlation) needs to be adjusted. However, many subjects had 2 different schools during observations due to progression from elementary to middle or middle to high school, which makes it difficult to adjust intra-school correlation in models. Therefore, intra-school district correlation, instead of intra-school correlation, was adjusted under the hypothesis that similarities in health behaviors and obesity of students were due to shared environment (i.e., PE policy) within the same school district. There were 3,805 subjects from 14 school districts.

In addition to intra-school district correlation, intra-individual correlation was adjusted in models, since each individual had a maximum of 3 or 4 time point measures. Correlation between repeated measures was adjusted using time variables. Similar to intra-school district correlation, time variable was not included in models as a fixed effect but adjusted in models using covariance structure. Time was coded as 1, 2, 3, and 4.

Question 1a, 1b, &1c

Research questions 1a, 1b, and 1c were to examine trajectories of physical activity, sedentary behaviors, and obesity.

1a. What are the trajectories of physical activity by age?

1b. What are the trajectories of sedentary behaviors by age?

1c. What are the trajectories of obesity by age?

Question 1 focused on the population trajectories of physical activity, sedentary behaviors and obesity when adjusting for intra-cluster correlation (intra-school district correlation) and intra-individual correlation (repeated measures). Trajectory was defined as how physical activity, sedentary behaviors, and obesity changed over time as subjects grew older. The first step was to examine crude mean changes of each variable by age groups across time (maximum 4 time points). Then linear, quadratic, and cubic relationships with age were examined using a mixed model method. Models with different covariance structure (i.e., CS-compound symmetry, AR(1)-first order autoregressive, and UN-unstructured) were fitted initially. UN (unstructured) was the best for all variables as all the models with UN had the lowest BIC compared to models with CS and AR(1). The final models for population trajectories were selected based on statistical significance from mixed models and how well the models fitted the changes of crude means. Statistical significance was determined by an alpha level of less than 0.05.

Trajectories of physical activity (question 1a) were examined separately in terms of (a) total, (b) low (LPA), (c) moderate (MPA), and (d) vigorous physical activity (VPA) scores in the full sample (8 to 19 years of age). Trajectories of sedentary behaviors (question 1b) were investigated separately in terms of hours of (a) TV viewing, (b) video games, and (c) computer use. Due to missing information of sedentary behaviors in cohort 5 (elementary school cohort), trajectories of TV viewing and video games were assessed in subjects aged 10 to 19 years. The trajectory of computer use was analyzed in subjects aged 13 to 19. Trajectories of obesity (question 1c) were explored in terms of (a) BMI, (b) BMI z score, (c) sum of skinfold thickness (SSF), and (d) waist circumference. Trajectory of waist circumference was examined in cohort 3, 4, and 5 subjects (elementary and high school cohorts) due to missing information in cohort 1 & 2 (middle school cohort).

Because of non-normal distribution (skewed distribution) in hours of video game use and SSF, these variables were initially transformed using square root and log. The transformation differed by each variable in terms of residual plots. According to residual plots, squared rooted transformation was best for hours of video game use and log transformation was best for SSF in terms of normality assumption of residuals.

Question 2

Do puberty, gender, race, and parental characteristics (family income, parental education, activity, and BMI risk) influence physical activity across age (as subjects grow older)?

Unlike question 1a to 1c, question 2 focused on relationships between physical activity (outcome variable) and predictors (gender, race, puberty, and parental characteristics) across age. The question was able to assess how initial status (intercept) and rate of change (slope) in physical activity different by puberty, gender, race, and parental characteristics.

There are 4 physical activity outcomes: total PA, LPA, MPA, and VPA. Question 2 was answered for each of the PA outcomes using 4 steps. First, longitudinal bivariate analysis was conducted to understand how each predictor variable was associated with the outcome variable across age. That is, longitudinal bivariate relationships included the main effect of a predictor and the interaction effect between predictor and age on the outcome variable. For instance, the bivariate relationship between puberty (predictor) and PA score (outcome) included the main effect of puberty and the interaction between puberty and age on the PA score. The next step was to construct models including child variables: main effects of child variables (puberty, gender, and race) and the interaction effects between child variables and age on the PA scores. Fitting models with only child variables was due to missing information of parental characteristics in about 40% of the sample. The third step was to fit a full model including all predictors (child and parental characteristics). In this process, parameter estimates from the full model were compared to ones from the model with child variable to detect possible multicolinearity. The last step was to run a reduced model (final model) including only significant variables from the full model. The significance was determined by p value less than 0.05.

In short, the following models were fitted step by step: longitudinal relationship between (a) each predictor and each PA score (Bivariate relationships), (b) all child variables and each PA score, (c) all predictors (child and parental variables) and each PA score (Full model), and (d) only significant predictors from full model and each PA score (Final model). PA scores were represented as total, LPA, MPA, and VPA scores in separate models. Thus, the analyses were repeated using different outcome variables. While gender, race, and parental characteristics were dealt with time-invariant variables, age and pubertal status were included as time-variant variables.

Question 3

Do puberty, gender, race, and parental characteristics influence sedentary behaviors across age (as subjects grow older)?

Question 3 examined relationships between sedentary behaviors and predictor variables across age. The procedure was the same as used in research question 2 except the outcome variables were three sedentary behaviors. Sedentary behaviors were indicated as time spent on watching TV, playing video games, and using computers, all in separate models. Since one cohort (cohort 5) had no information about sedentary behaviors, models with TV and video games were analyzed in subjects aged 10 to 19 and models with computer use in subjects aged 13 to 19. Time spent on video games was transformed with squared root as noted in research question 1.

Question 4

Are sedentary scores inversely related to moderate, vigorous or total PA scores across age, when puberty, gender, race, and parental characteristics are controlled in the model?

Unlike question 2 or 3, in this question, puberty, gender, race, and parental characteristics were not predictors but control variables, because the research focus of this question was to examine the relationship between sedentary behaviors and physical activity. Thus, the following models were tested step by step: longitudinal relationship between (a) sedentary behaviors and PA scores (Bivariate relationships), (b) sedentary behaviors and PA scores, when controlling for child variables, (c) sedentary behaviors and PA scores, when controlling for both child and parental variables (Full model), and (d) sedentary behaviors and PA scores, when adjusting for significant covariates from the full model (final model). These models were repeatedly fitted using each sedentary behavior and each PA score variable: sedentary behaviors (hours of TV, video games, and computer use) and PA scores (MPA, VPA, and total PA score).

Question 5

To what extent is child obesity predicted by moderate or vigorous or total physical *activity scores across age, when puberty, gender, race, sweet drink intake, and parental characteristics are controlled in the model?*

The longitudinal relationships between obesity and physical activity were investigated, when adjusting for child and parental variables. The procedure was the same as used in research question 4. Obesity, the outcome variable, was examined in separate models as (a) BMI, (b) BMI z score, (c) SSF, and (d) waist circumference (only available for CHIC III subjects: elementary and high school cohorts). Physical activity, a predictor variable (time variant variable), was represented with (a) MPA, (b) VPA, and (c) total PA score in separate models. Although intake of sweet drinks was included as a covariate in the question, it was not significantly related to obesity ($p>0.05$) from step 1 to 4. Thus, intake of sweet drinks was excluded in the models with child variables, full models, and final models because more than half of sample had no information about sweet drink intake. SSF was log-transformed as noted above.

Question 6

To what extent is child obesity predicted by sedentary behaviors across age, when puberty, gender, race, sweet drink intake, and parental characteristics are controlled in the model?

To answer this question, the same procedure as used in question 5 was employed in the sample using sedentary behavior information (TV and video games: ages 10 to 19; computer: ages 13 to 19). Sedentary behaviors (independent variable, time-variant variable) were represented as hours of (a) TV, (b) video games, and (c) computer use per week in separate models. Obesity was indicated as BMI, BMI z score, log-transformed SSF, and waist circumference in separate models. Intake of sweet drinks was only included in the model with video and covariates (child variables) to predict BMI since sweet drinks did not show any statistical significance in other models and more than half of the sample had no information about intake of sweet drinks.

Question 7

Is there an interaction between physical activity and sedentary behavior and obesity across age when puberty, gender, race, parental characteristics are controlled in the model?

Unlike question 5 and 6, this question included interactions between physical activity and sedentary behaviors to predict obesity. To answer research question 7, sedentary behaviors were represented as hours of TV viewing, video games, or computer use per week in separate models. Physical activity was indicated as (a) MPA, (b) VPA, or (c) total PA scores in separate models. Obesity was also represented using either BMI, BMI z score, SSF, or waist circumference in separate models. The same procedures as used in question 5 or 6 were employed. SSF was log-transformed.

CHAPTER 4

RESULTS

There were 3,805 subjects who had observations over time either obesity, physical activity, or sedentary behaviors. The sample was composed of 52 percent girls and 48 percent boys; 58 percent white and 42 percent black (Table 4.1.1). Means and SDs of time invariant child variables (age and puberty) are shown in Table 4.1.2. Mean ages progressed over time. The difference of mean ages between time 3 and 4 was greater than 1 year, because there were no measurements for the elementary school cohort at time 4. About 65 to 70% of subjects had at least 1 parental characteristic (family income, parental education, activity, or BMI risk). Table 4.1.3 provides the frequency and percentage of parental characteristics of the sample.

Means and SDs of physical activity, sedentary behaviors, obesity, and sweet drink intake at each time point are presented in Table 4.1.4. Tables 4.1.5 and 4.1.6 show means, SDs, and number of observation on physical activity, sedentary behaviors, obesity, and sweet drink intake at each age. Intercorrelations of physical activity scores, sedentary behaviors, and obesity indicators between each time point are shown in Table 4.1.7. The highest correlations were found in BMI (0.91 to 0.97) and BMI z score (0.87 to 0.96) and waist circumference (0.87 to 0.94) and the lowest in computer use (0.22 to 0.51).

Table 4.1.1

Gender and Race of the Sample

		N	%
Gender			
Girls		1,987	52.2
Boys		1,818	47.8
Race			
Black(overall)		1,610	42.3
	Girls	876	23.0
	Boys	734	19.3
White (overall)		2,195	57.7
	Girls	1,111	29.5
	Boys	1,084	28.5

Table 4.1.2

Age and Puberty at Each Time Point (Means and SDs)

	Time 1	Time 2	Time 3	Time 4
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age (N)	3,681	2,505	2,112	861
(Years)	12.6 (2.3)	13.5 (2.5)	13.9 (2.2)	16.1 (1.1)
Puberty (N)	3,532	2,455	1,984	830
(Stage)	3.0 (1.1)	3.3 (1.0)	3.5 (0.9)	4.1 (0.7)

Table 4.1.3

Frequency and Percentage of Parental Characteristics

	Category	Frequency (N)	Percent (%)
Family Income [1]	~ $ 19,999	811	32.3
	20,000 - 39,999	833	33.1
	40,000 - 74,999	686	27.3
	75,000 ~	185	7.4
Parental Education [2]	Less than high school	285	10.8
	High school graduate	785	29.7
	Some college	855	32.3
	College graduate or more	720	27.2
Parental Activity [3]	Less than 1 per month	545	20.7
	1-3 time per month	609	23.1
	1-2 per week	582	22.1
	3 or more per week	896	34.0
Parental BMI risk [4]	<25	640	24.7
	$\geq 25, <30$	996	38.5
	$\geq 30, <35$	564	21.8
	≥ 35	390	15.0

[1] Frequency Missing = 1290
[2] Frequency Missing = 1160
[3] Frequency Missing = 1173
[4] Frequency Missing = 1215

Table 4.1.4

Physical Activity, Sedentary Behaviors, Obesity, Sweet Drink Intake at Each Time Point

	Time 1	Time 2	Time 3	Time 4
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Physical Activity (MET*Frequency/week)				
(N)	3,479	2,386	2,016	838
Tot PA	238.1 (132.7)	214.0 (131.8)	201.1 (120.2)	121.3 (61.1)
LPA	62.9 (27.2)	55.6 (28.6)	56.7 (25.5)	40.2 (17.3)
MPA	67.0 (41.1)	59.4 (40.8)	55.4 (37.8)	23.4 (24.8)
VPA	108.2 (78.4)	99.0 (75.8)	89.0 (70.8)	46.8 (39.8)
Sedentary Behaviors (Hours per week)				
TV (N)	2,301	1,407	1,094	845
	16.4 (6.9)	15.9 (7.0)	15.9 (6.9)	14.5 (7.4)
Video (N)	2,298	1,405	1,095	847
	5.8 (7.2)	4.9 (6.8)	4.2 (6.3)	4.4 (7.1)
Computer(N)	517	658	391	209
	9.5 (7.4)	9.3 (7.2)	9.3 (7.3)	8.8 (7.3)
Obesity (BMI-Kg/m^2, SSF-mm, waist-cm)				
BMI (N)	3,546	2,425	2,005	825
	22.05 (5.64)	22.79 (5.76)	23.30 (5.96)	24.10 (5.60)
BMI z (N)	3,546	2,425	2,005	825
	0.73 (1.08)	0.75 (1.06)	0.77 (1.07)	0.64 (1.01)
SSF (N)	3,537	2,409	1,998	823
	29.41 (16.75)	30.19 (17.01)	30.89 (17.38)	32.20 (16.84)
Waist (N)	1,814	1,678	1,351	210
	71.78 (14.85)	74.34 (14.46)	74.88 (14.49)	81.17 (14.37)
Sweet Drink (Frequency per day)				
Sweet drink	2,510	1,602	1,230	182
(N)	2.3 (1.9)	2.1 (1.8)	1.9 (1.5)	2.5 (2.2)

Table 4.1.5

Means, SDs, and Number of Observation on Physical activity and Sedentary Behaviors at Each Age

		Physical Activity (MET*session/week)				Sedentary Behaviors (Hours per week)		
Age		Total PA	LPA	MPA	VPA	TV	Video	Computer
8	N	170	170	170	170			
	M	365.4	89.2	98.0	178.2			
	(SD)	(92.2)	(21.3)	(33.2)	(62.2)			
9	N	470	470	470	470			
	M	377.7	87.4	102.1	188.3			
	(SD)	(96.8)	(20.3)	(34.3)	(64.4)			
10	N	874	874	874	874	1	1	0
	M	374.7	88.6	102.4	183.7	24.5	12.5	
	(SD)	(91.7)	(21.0)	(33.6)	(59.9)	(.)	(.)	
11	N	1008	1008	1008	1008	184	185	0
	M	292.6	72.6	80.0	140.0	16.7	6.5	
	(SD)	(127.9)	(26.0)	(41.4)	(76.0)	(6.9)	(7.1)	
12	N	1371	1371	1371	1371	770	769	0
	M	210.3	57.9	60.2	92.3	16.4	6.1	
	(SD)	(105.1)	(23.9)	(35.1)	(62.9)	(6.6)	(7.0)	
13	N	1196	1196	1196	1196	1051	1048	2
	M	179.2	50.9	52.7	75.5	16.6	5.8	1.8
	(SD)	(87.1)	(19.9)	(30.5)	(54.7)	(6.7)	(7.4)	(2.5)
14	N	1113	1113	1113	1113	1084	1080	97
	M	159.0	46.3	46.4	66.3	16.4	5.0	10.9
	(SD)	(81.1)	(19.6)	(29.3)	(50.1)	(6.8)	(6.8)	(7.6)
15	N	965	965	965	965	973	974	311
	M	136.8	41.9	39.3	55.6	15.5	4.3	9.6
	(SD)	(70.7)	(18.0)	(27.7)	(43.7)	(7.1)	(6.5)	(7.3)
16	N	772	772	772	772	786	784	583
	M	114.8	40.0	30.4	44.3	15.2	4.1	9.2
	(SD)	(63.8)	(17.9)	(24.5)	(40.9)	(7.4)	(6.4)	(7.2)
17	N	631	631	631	631	644	649	628
	M	107.1	38.6	28.4	40.1	14.7	4.4	9.2
	(SD)	(60.3)	(17.6)	(22.6)	(40.7)	(7.3)	(7.2)	(7.2)
18	N	137	137	137	137	145	146	145
	M	105.3	34.5	25.4	45.4	14.6	5.0	8.6
	(SD)	(56.4)	(17.8)	(20.5)	(40.7)	(7.5)	(7.7)	(7.5)
19	N	9	9	9	9	9	9	9
	M	57.1	31.7	13.3	12.0	20.6	6.0	6.6
	(SD)	(31.9)	(12.1)	(12.1)	(19.9)	(4.4)	(8.5)	(8.6)

Table 4.1.6

Means, SDs, and Number of Observation on Obesity and Sweet Drink Intake at Each Age

		Obesity (SSF: mm, Waist Circumference: cm)				Sweet Drink Intake (Frequency per week)
Age		BMI	BMI z	SSF	Waist	Sweet Drink Intake
8	N	198	198	198	198	165
	M	18.87	0.73	21.80	61.97	1.8
	(SD)	(4.10)	(1.07)	(12.89)	(9.88)	(1.03)
9	N	515	515	515	515	464
	M	19.80	0.78	24.76	65.34	1.7
	(SD)	(4.52)	(1.06)	(14.55)	(11.27)	(1.0)
10	N	919	919	917	914	859
	M	21.19	0.86	28.49	69.16	1.7
	(SD)	(5.36)	(1.12)	(16.74)	(12.99)	(1.0)
11	N	1051	1051	1039	859	797
	M	21.81	0.82	29.43	72.02	1.8
	(SD)	(5.52)	(1.10)	(16.73)	(13.86)	(1.1)
12	N	1376	1376	1363	613	764
	M	22.39	0.77	31.43	75.08	1.9
	(SD)	(5.71)	(1.08)	(17.24)	(14.67)	(1.56)
13	N	1169	1169	1166	158	436
	M	22.70	073	30.95	76.26	2.2
	(SD)	(5.25)	(1.02)	(16.17)	(14.70)	(1.93)
14	N	1061	1061	1059	123	371
	M	23.27	0.68	31.13	78.93	2.6
	(SD)	(5.49)	(1.01)	(16.92)	(15.11)	(2.3)
15	N	933	933	932	307	420
	M	23.95	0.67	31.54	80.05	2.7
	(SD)	(5.90)	(1.02)	(17.40)	(14.85)	(2.4)
16	N	770	770	768	576	538
	M	24.98	0.71	32.39	80.48	2.7
	(SD)	(6.29)	(1.06)	(18.41)	(14.11)	(2.3)
17	N	652	652	653	633	574
	M	25.0	0.59	31.67	80.63	2.5
	(SD)	(6.22)	(1.07)	(17.98)	(14.31)	(2.3)
18	N	145	145	145	145	129
	M	24.41	0.41	27.51	78.99	2.3
	(SD)	(5.08)	(1.10)	(15.46)	(11.70)	(2.0)
19	N	9	9	9	9	7
	M	27.16	0.56	38.61	85.92	1.9
	(SD)	(9.97)	(1.43)	(26.22)	(24.22)	(1.5)

Table 4.1.7

Intercorrelations for Physical Activity Scores, Sedentary Behaviors, and Obesity (correlation between each time point)

	Physical Activity				Sedentary Behaviors				Obesity		
	Total PA				TV				BMI		
Time	2	3	4		2	3	4		2	3	4
1	0.67	0.57	0.39	1	0.58	0.45	0.39	1	0.96	0.94	0.91
2		0.67	0.46	2		0.62	0.55	2		0.97	0.93
3			0.50	3			0.57	3			0.96
	LPA				Video				BMI z score		
	2	3	4		2	3	4		2	3	4
1	0.59	0.52	0.31	1	0.59	0.49	0.33	1	0.95	0.92	0.87
2		0.60	0.33	2		0.54	0.31	2		0.96	0.90
3			0.49	3			0.41	3			0.95
	MPA				Computer				SSF		
	2	3	4		2	3	4		2	3	4
1	0.56	0.45	0.29	1	0.51	0.40	0.25*	1	0.83	0.86	0.81
2		0.56	0.41	2		0.48	0.22**	2		0.83	0.83
3			0.45	3			0.40	3			0.90
	VPA								Waist		
	2	3	4						2	3	4
1	0.64	0.54	0.41					1	0.92	0.91	0.87
2		0.64	0.48					2		0.94	0.89
3			0.49					3			0.92

Note. p for all <0.0001, except * p=0.0035, **p=0.0019

Research Question 1

Question 1 was (a) “What are the trajectories of physical activity by age?” (b) “What are the trajectories of sedentary behaviors by age?” and (c) “What are the trajectories of obesity by age?”

Trajectories of Physical Activity

The total number of observations was 8,716. Crude mean changes of PA variables showed that the youngest children (ages 8 to 10) had the highest level of activity scores and the scores decreased with age. All physical activity scores decreased rapidly between ages of 10 to 12 and then the scores diminished slowly (Figure 4.1.1). The vertical axis of figures for LPA, MPA, and VPA changes was set to 0 to 200 in order to more easily show the changes across age, but the figure for total PA has a higher axis because total PA is a sum of 3 scores. Table 4.2.1 shows that all PA score variables had significant linear, quadratic, and cubic relationships with age (p for all <0.0001). Even though the cubic models were significant and had the lowest BIC (102082.9 for total PA, 76831.8 for LPA, 84128.1 for MPA, and 93765.1 for VPA), the quadratic models for all PA variables were selected as the final one (population model) because the quadratic models fitted best with the crude mean changes. The population model (Figure 4.1.2) showed that vigorous activity decreased more rapidly than low and moderate intensity activity.

Figure 4.1.1

Observed Mean Values of (1) Total, (2) LPA, (3) MPA, and (4) VPA over Age by Age at Entry into Study (Note: The axis for Total PA is greater than the others)

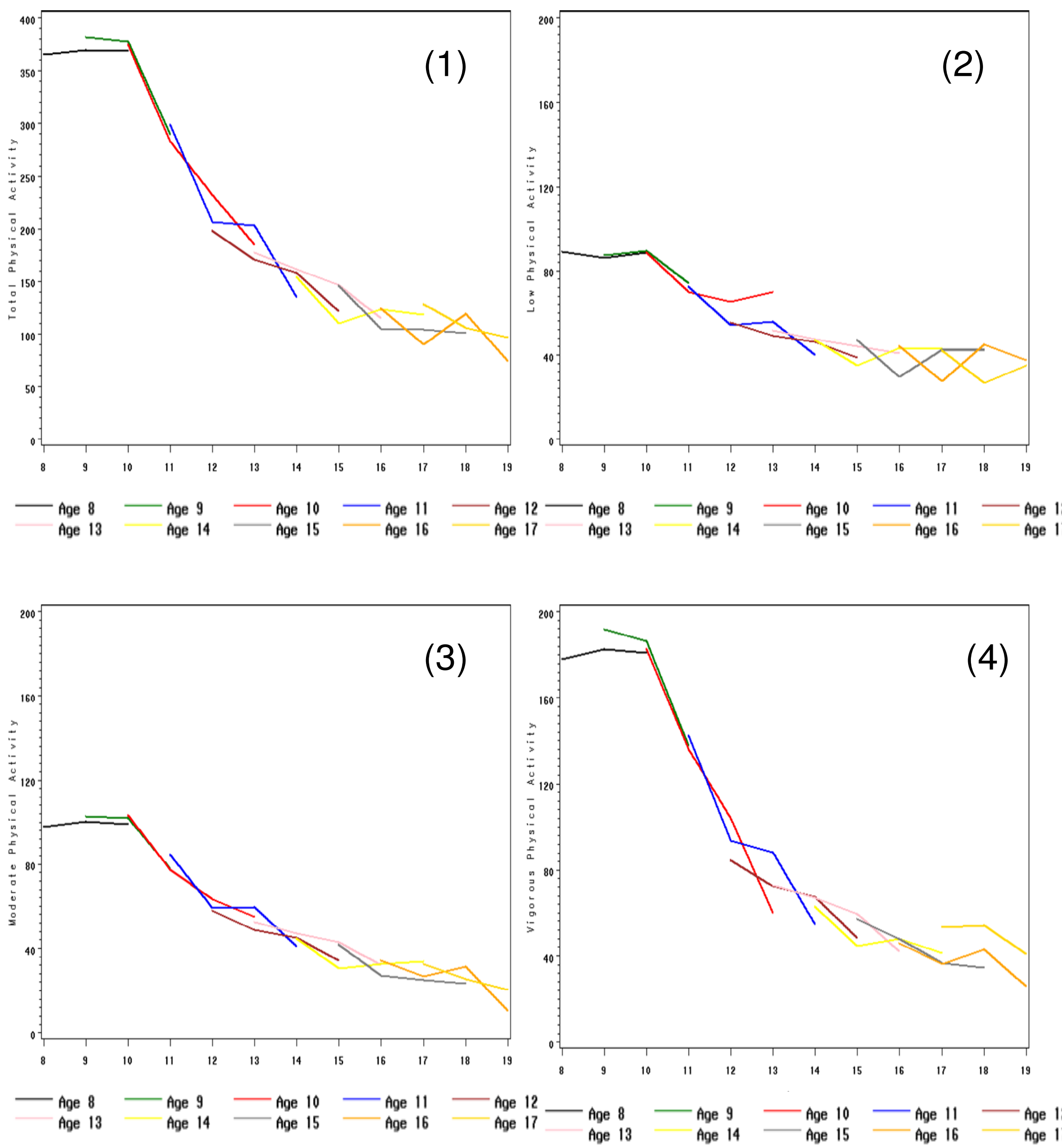


Figure 4.1.2

Population Trajectories of Physical Activity over Age

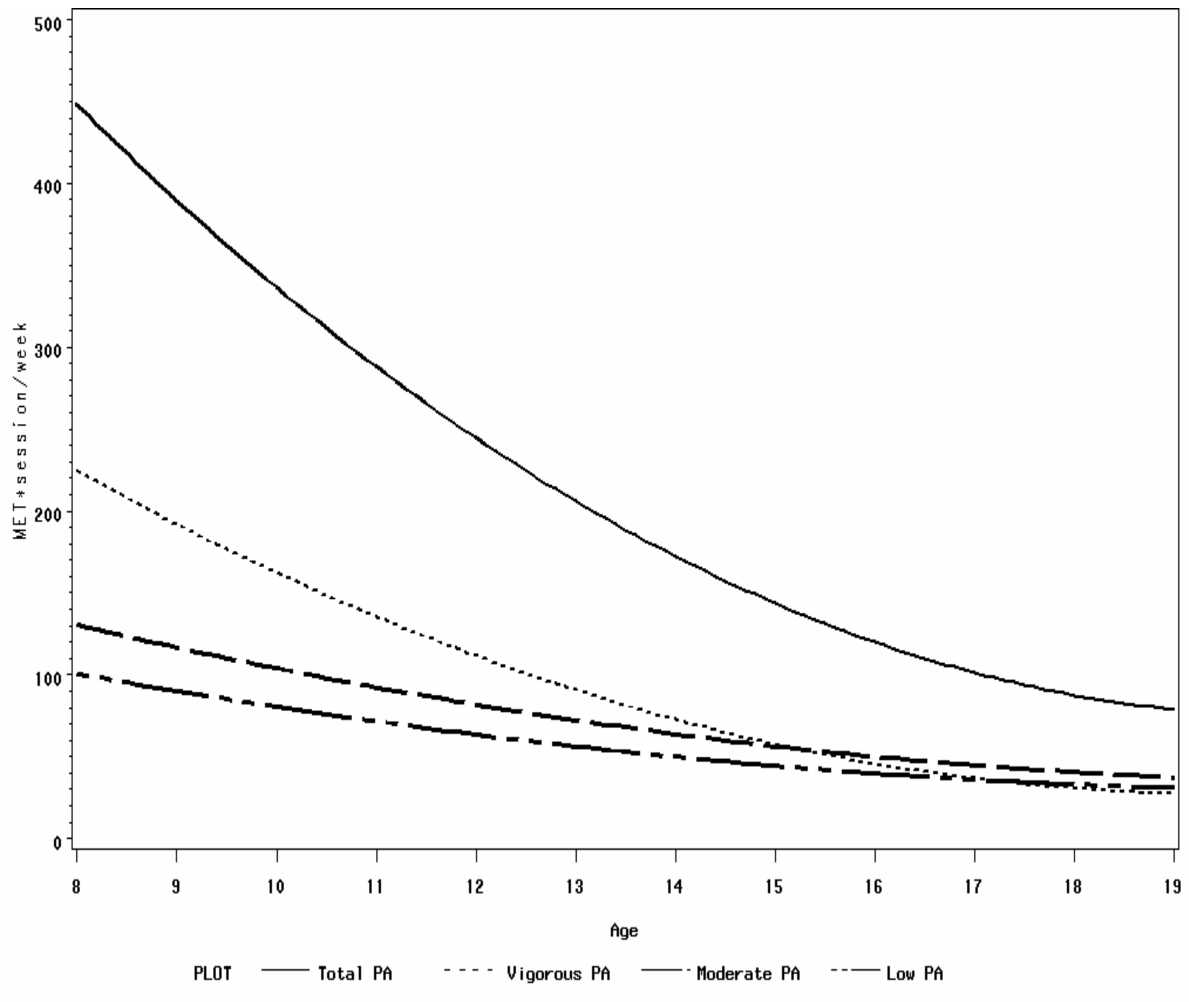


Table 4.2.1

Models for Trajectories of Physical Activity over Age *(Number of Observation: 8,716)*

		Intercept			age			Age^2			Age^3			
		B	SE	p	β	SE	P	β	SE	p	β	SE	p	BIC
Total PA	Linear	626.47	10.69	<0.0001	-31.71	0.46	<0.0001							102292.5
	Quadratic	1092.95	34.58	<0.0001	-100.4	4.92	<0.0001	2.47	0.18	<0.0001				102111.6
	Cubic	366.78	128.94	0.0045	69.48	29.52	0.0186	-10.41	2.22	<0.0001	0.32	0.05	<.0001	102082.9
LPA	Linear	137.10	2.39	<0.0001	-6.11	0.11	<0.0001							76949.8
	Quadratic	215.93	8.02	<0.0001	-17.82	1.15	<0.0001	0.43	0.04	<0.0001				76856.1
	Cubic	50.32	30.44	0.0984	21.16	7.01	0.0025	-2.55	0.53	<0.0001	0.07	0.01	<0.0001	76831.8
MPA	Linear	178.97	3.15	<0.0001	-9.08	0.16	<0.0001							84208.8
	Quadratic	278.60	12.23	<0.0001	-23.78	1.76	<0.0001	0.53	0.06	<0.0001				84145.7
	Cubic	61.77	46.77	0.1867	27.08	10.74	0.0117	-3.34	0.81	<0.0001	0.1	0.02	<0.0001	84129.1
VPA	Linear	314.42	6.23	<0.0001	-16.83	0.29	<0.0001							93948.2
	Quadratic	593.25	21.38	<0.0001	-57.87	3.06	<0.0001	1.48	0.11	<0.0001				93778.7
	Cubic	255.43	80.05	0.0014	21.18	18.33	0.2479	-4.52	1.38	0.0010	0.15	0.03	<0.0001	93765.1

Note. Covariance Structure: UN

Trajectories of Sedentary Behaviors

The total numbers of observations were 5,677 (TV), 5,645 (Video), and 1,775 (Computer). The crude mean change graphs showed that hours of TV viewing peaked at the ages of 11 and 12 years, decreased until the age of 18 years, and rebounded at the age of 19 years (Figure 4.1.3). Hours of TV per week had a significant linear ($p<0.0001$), quadratic ($p=0.0113$), and cubic ($p=0.0003$) relationship with age (Table 4.2.2). The cubic model was selected as the final model as it had the smallest BIC (36459.4) and best fit with the crude mean changes. According to the final model (population model), there was a slight decrease in hours of TV viewing from the age of 13 to 17 years (17.4 to 14.4 hours per week). Even though there was an increase from the age of 10 to 12 years and a rebounding trend from the age of 17 to 19 years, those results are questionable due to small number of samples at ages 10, 11, and 19 years.

Hours of video games were non-normally distributed. Thus, crude median change, instead of mean change, was examined, because the mean was influenced by extreme values. Crude median changes showed that hours of video games peaked at the age of 10 and 11 years, diminished until the age of 18 years, and rebounded at the age of 18 and 19 years (Figure 4.1.4). Square rooted hours of video showed significant linear ($p<0.0001$), quadratic (<0.0001) and cubic ($p=0.0017$) relationships with age (Table 4.2.2). The quadratic model was chosen as the final population model because it had the smallest BIC (19655.6) and fitted best with crude median changes. The population model presents a slight drop in hours of video games from the age of 12 to 18 years (3.6 to 0.9 hours per week).

Hours of computer use had no trend in crude mean change with age (Figure 4.1.5). Linear, quadratic, and cubic relationships with age were not significant (Table 4.2.2).

Figure 4.1.3

Observed Mean Values and Population Trajectory of Hours of TV viewing per Week over Age

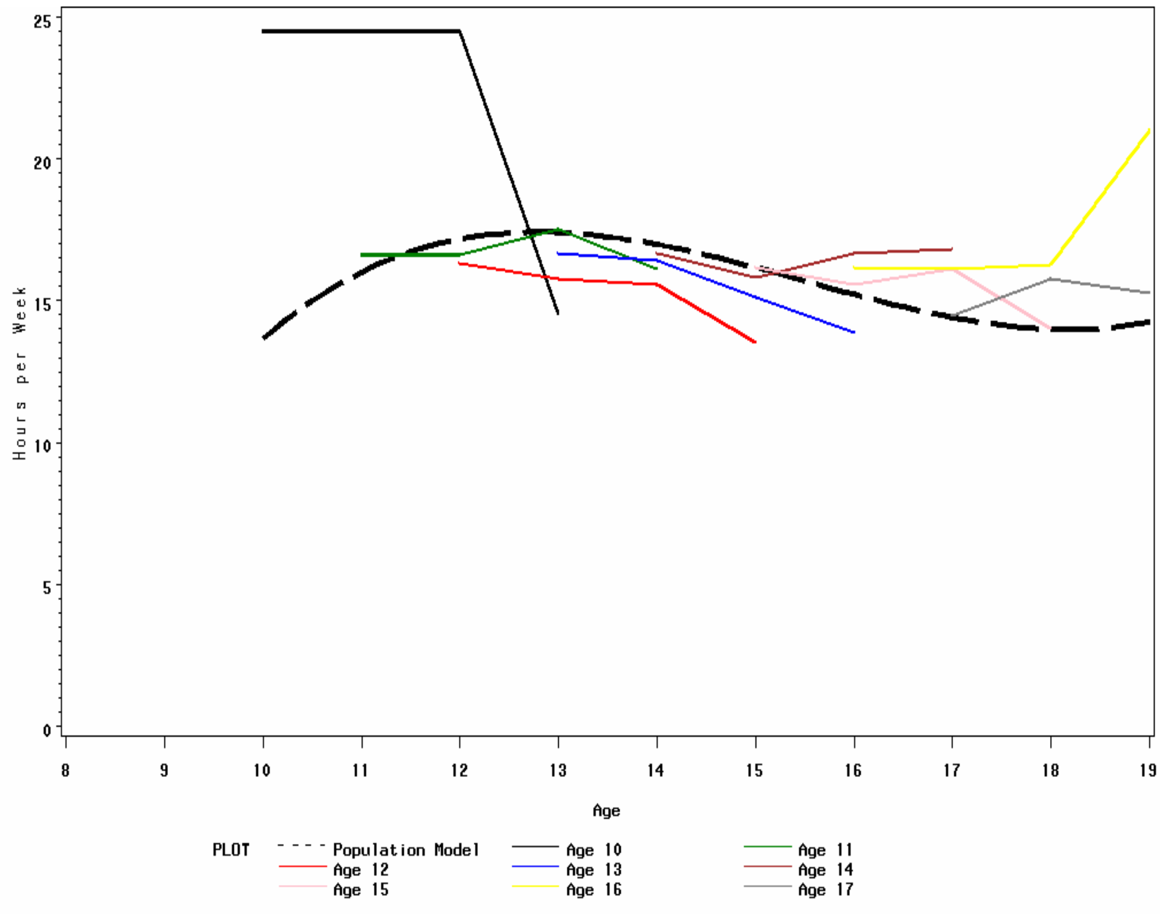


Figure 4.1.4

Observed Mean Values and Population Trajectory of Hours of Video Games per Week over Age

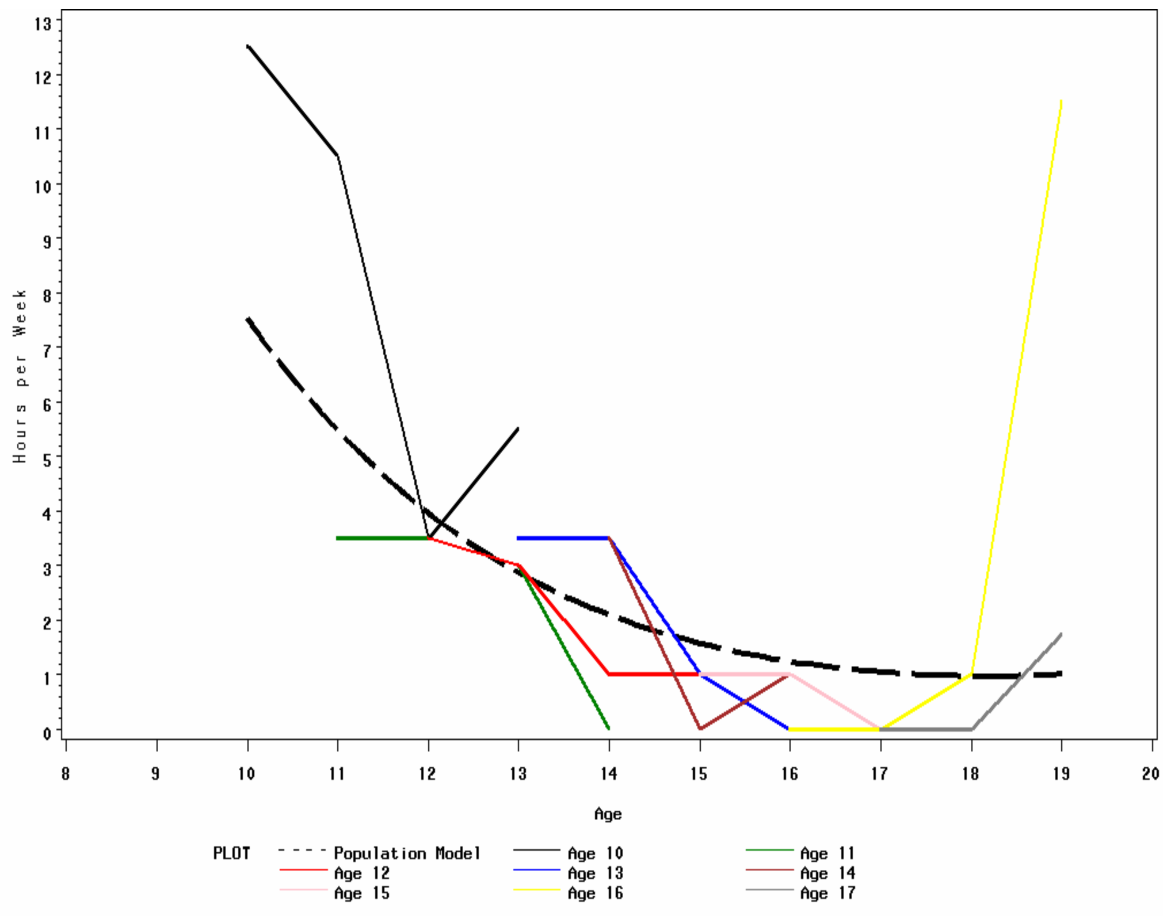


Figure 4.1.5

Observed Mean Values of Computer Use per Week over Age by Age at Entry into Study

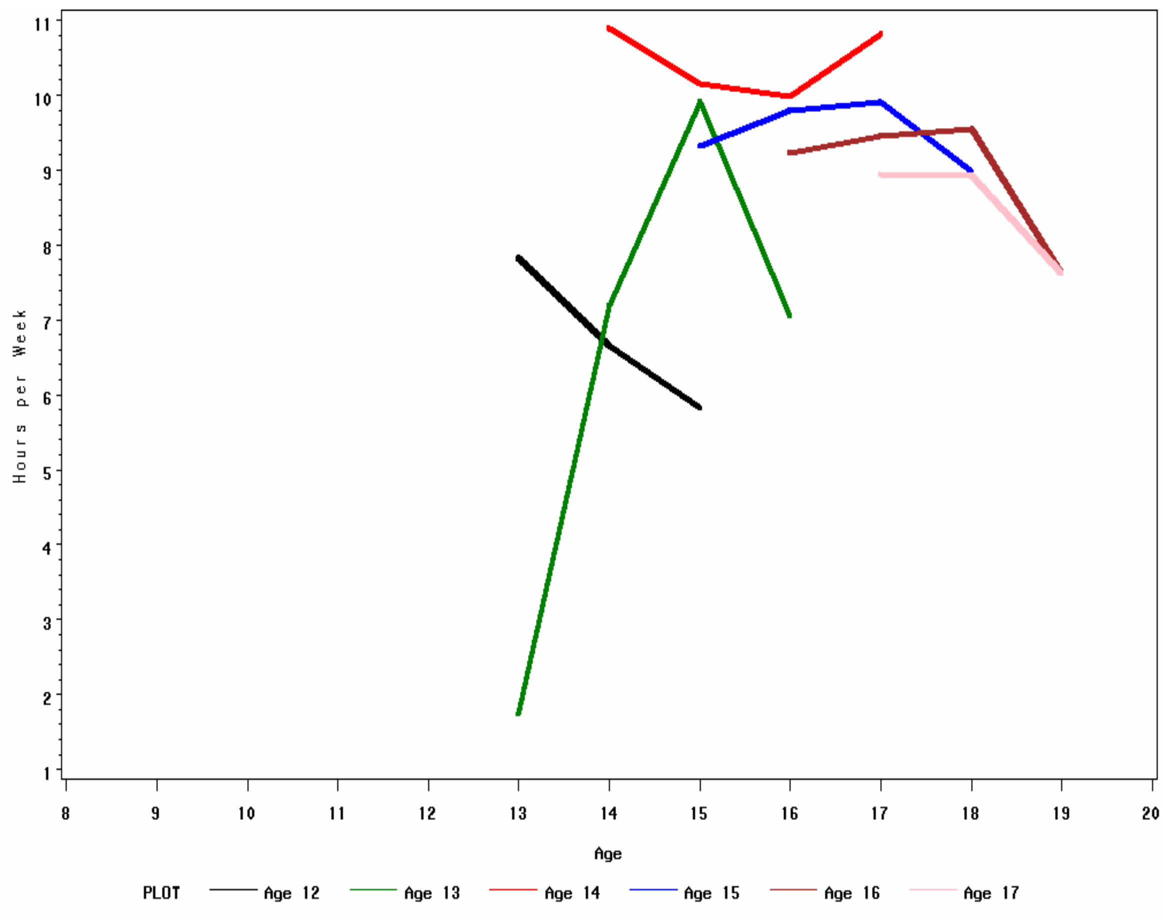


Table 4.2.2

Models for Trajectories of Sedentary Behaviors over Age

		Intercept			age			Age^2			Age^3			
(N of obs)		B	SE	p	β	SE	p	β	SE	p	β	SE	p	BIC
TV (5647)	Linear	25.11	1.0	<0.0001	-0.61	0.06	<0.0001							36466.3
	Quadratic	11.14	5.61	0.0472	1.31	0.76	0.0850	-0.06	0.03	0.0113				36465.4
	Cubic	-133.21	40.1	0.0009	30.75	8.13	0.0002	-2.05	0.55	0.0002	0.04	0.01	0.0003	36459.4
Square Rooted Video (5645)	Linear	3.83	0.2	<0.0001	-0.17	0.01	<0.0001							19668.6
	Quadratic	9.59	1.22	<0.0001	-0.96	0.17	<0.0001	0.03	0.01	<0.0001				19655.6
	Cubic	-12.94	9.01	0.1511	3.64	1.83	0.0467	-0.28	0.12	0.0213	0.001	0.003	0.0117	19659.2
Computer (1775)	Linear	12.29	2.88	<0.0001	-0.21	0.17	0.2200							11816.8
	Quadratic	-4.37	33.65	0.8966	1.81	4.06	0.6563	-0.06	0.12	0.6196				11819.0
	Cubic	51.54	394.25	0.8960	-8.38	71.7	0.9070	0.56	4.34	0.8980	-0.01	0.09	0.8869	11822.0

Note. Covariance Structure: UN

Trajectories of Obesity

Total numbers of observations were 8,978 for BMI and BMI z, 8,764 for SSF and 5,050 for waist circumference. According to the crude mean change, BMI increased with age. BMI in younger subjects increased slightly faster compared with older subjects (Figure 4.1.6). BMI had a significant linear and quadratic relationship with age; p for both <0.0001 (Table 4.2.3). The quadratic model was selected as the final one as it had the smaller BIC (41353.6) and fitted best with crude mean change.

Crude mean change of BMI z score showed a slight increase from the age of 8 to 13 or 14 years and a decrease later (Figure 4.1.7). The quadratic model was the only significant one (p<0.0001). Therefore, the quadratic model was selected as the final model. According to this model, BMI z score increased from the age of 8 (BMI z=0.577) to 14 years (BMI z=0.764) and decreased until the age of 19 years (BMI z=0.606).

SSF (Sum of Skinfold thickness) was log-transformed due to non-normal distribution. Therefore, crude median, instead of mean, was used to examine the changes by age. Crude median change of SSF showed slightly greater increase between the age of 8 and 13 years and the increasing rate became flattened except a rapid increase from the age of 18 to 19 years (Figure 4.1.8**).** However, the rebound increase at the age of 19 years is questionable due to the very small number of subjects (N=9). Linear, quadratic, and cubic models were significant; p for all <0.0001. The quadratic model was chosen as the final population model as it fitted best with the crude median change. According to the population model, SSF rapidly increased from the age of 8 to 14 years and then it flattened.

Mean change of waist circumference showed an increasing trend with age (Figure 4.1.9). The mixed model results showed significant linear and quadratic relationships with age; p for both <0.0001. The quadratic model was selected as the final model due to the smallest BIC (34707.7) and best fit with crude mean change. The population model showed more rapid increase in waist circumference from the age of 8 to 14 or 15 years and the rate of increase became slower.

Summary

In sum, all physical activity scores decreased rapidly during the ages of 10 to 13 years and then diminished slowly by the age of 19 years. Vigorous activity decreased faster than low and moderate activity. A faster drop of physical activity during the ages of 10 to 13 years was paralleled by a rapid increase of obesity. BMI increased with age; younger subjects increased slightly faster than older subjects. SSF increased from the ages of 8 to 13 and then flattened. Similar to BMI, waist circumference increased with age with a more rapid increase in younger subjects. Unlike other obesity indicators, BMI z score showed a different trend across age: it increased from the ages of 8 to 14 years and decreased later. While physical activity decreased, sedentary behaviors (hours of TV and video games) also decreased around 12 to 18 years of age. Hours of computer use showed no significant trend by age,

Figure 4.1.6

Observed Mean Values and Population Trajectory of BMI over Age

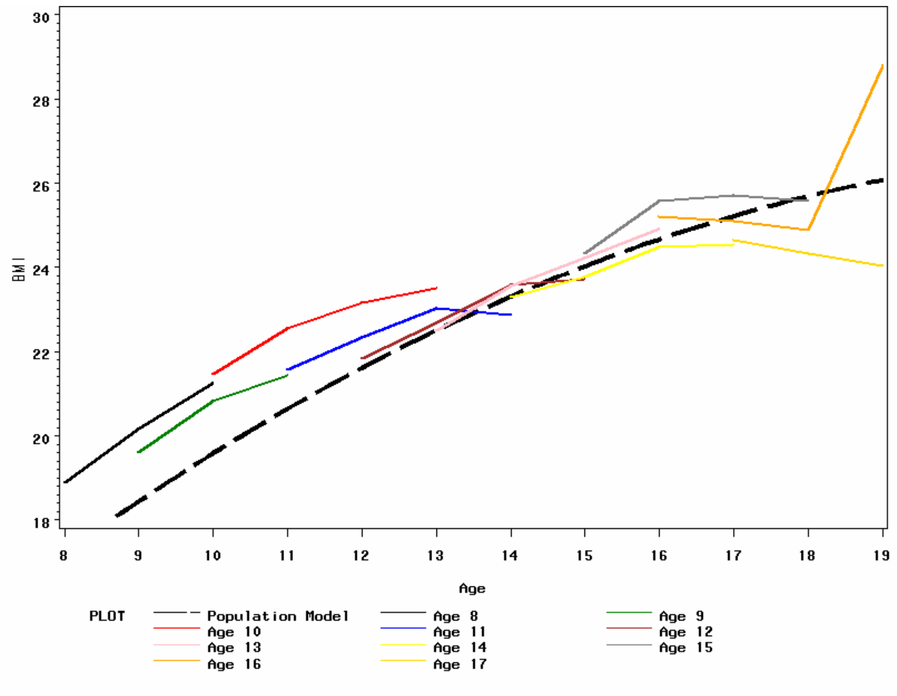


Figure 4.1.7

Observed Mean Values and Population Trajectory of BMI z score over Age

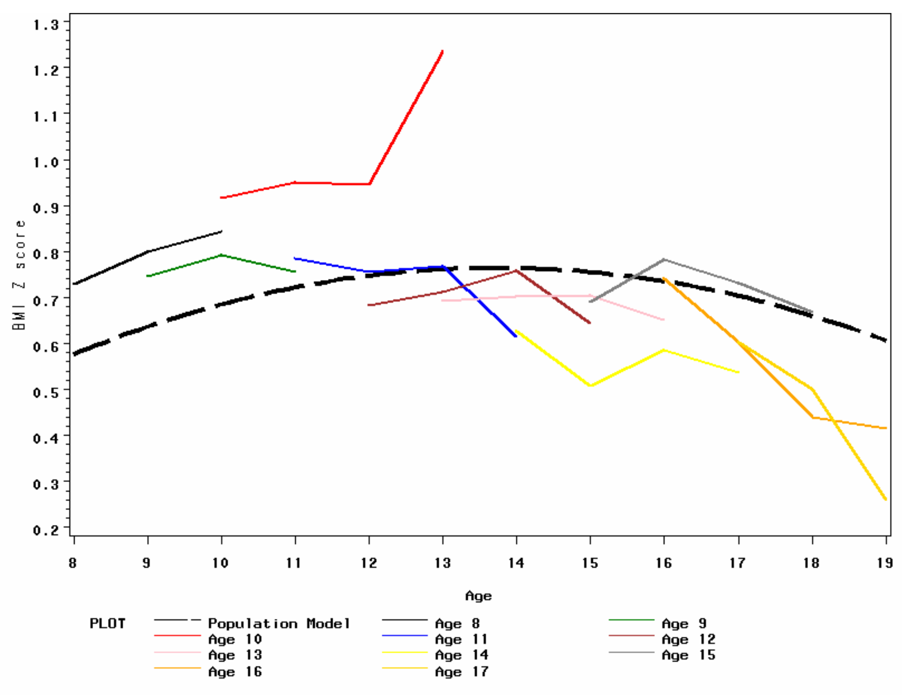


Figure 4.1.8

Observed Mean Values and Population Trajectory of SSF over Age

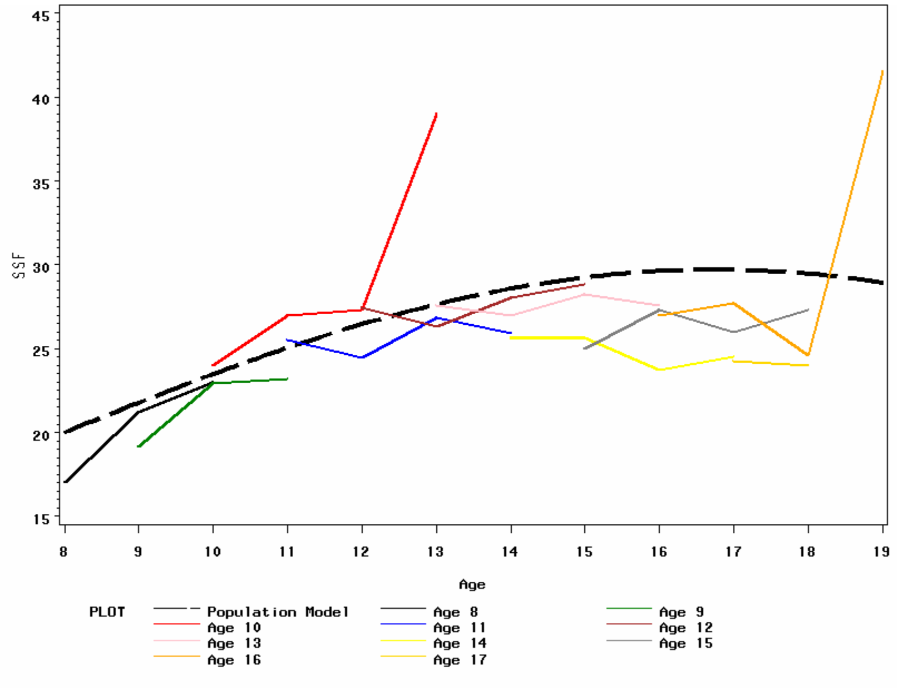


Figure 4.1.9

Observed Mean Values and Population Trajectory of Waist Circumference over Age

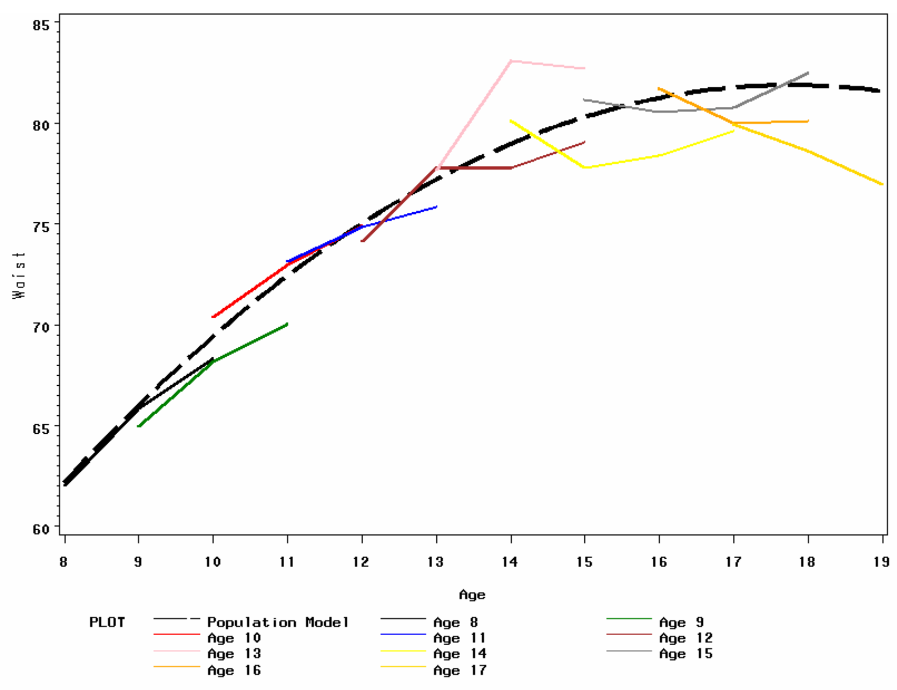


Table 4.2.3

Models for Trajectories of Obesity over Age

		Intercept			age			Age^2			Age^3			
(N of obs)		β	SE	p	β	SE	p	β	SE	p	β	SE	p	BIC
BMI (8798)	Linear	11.99	0.31	<0.0001	0.8	0.02	<0.0001							41439.6
	Quadratic	4.4	0.8	<0.0001	1.94	0.11	<0.0001	-0.04	0.004	<0.0001				41341.3
	Cubic	6.13	2.72	0.0241	1.53	0.62	0.0138	-0.01	0.05	0.8174	-0.001	0.001	0.5057	41352.6
BMI z (8798)	Linear	0.743	0.063	<0.0001	-0.0002	0.004	0.9556							14000.2
	Quadratic	-0.314	0.176	0.0745	0.157	0.025	<0.0001	-0.006	0.001	<0.0001				13971.2
	Cubic	0.164	0.607	0.7871	0.044	0.139	0.7499	0.003	0.01	0.7833	-0.0002	0.0003	0.410	13985.2
Log SSF (8764)	Linear	2.89	0.04	<0.0001	0.03	0.002	<0.0001							5688.3
	Quadratic	1.94	0.11	<0.0001	0.17	0.02	<0.0001	-0.01	0.001	<0.0001				5619.3
	Cubic	-1.49	0.39	0.0001	0.99	0.09	<0.0001	-0.07	0.01	<0.0001	0.002	0.0002	<0.0001	5553.3
Waist (5050)	Linear	48.97	1.35	<0.0001	1.99	0.07	<0.0001							34877.0
	Quadratic	16.65	2.65	<0.0001	7.35	0.39	<0.0001	-0.21	0.01	<0.0001				34700.0
	Cubic	5.74	10.87	0.5974	9.98	2.57	0.0001	-0.41	0.2	0.0371	0.01	0.005	0.2982	34707.7

Note. Covariance Structure: UN

Research Question 2

Question 2 was, “Do puberty, gender, race, and parental characteristics (family income, parental education, activity, and BMI risk) influence physical activity across age (as subjects grow older)?” The question was answered using 4 steps: (a) to examine longitudinal bivariate relationships (how each predictor was related to each physical activity score across age), (b) to fit models with child variables, (c) to fit full models including child and parental variables (full model), and (d) to fit reduced models including only significant variables from the full models (final model). Residual analysis as diagnostics of the final models was also performed. No odd fan or curved trends were found in residual plots, which manifest models are appropriate. Tables from the first 3 steps and all figures (except Figures 4.2.1 to 4.2.4) are in Appendix M. Selected bivariate graphs that reflect the reduced models are shown.

Longitudinal Bivariate Relationships

Puberty had significant main and interaction effects with age on all PA scores (p for all <0.0001). All PA scores decreased with age; total PA scores diminished faster at pubertal stages 1, 2, and 3 than at stages 4 and 5 (Figure 4.2.1); LPA, MPA, and VPA showed similar results (Figures 4.2.5 to 4.2.7 in Appendix M).

Sex had a significant main effect on Total PA and VPA and significant main and interaction effects with age on LPA, and no statistical significance on MPA. That is, boys had higher total PA (28.1 MET*session/week, p=0.0216) and VPA scores (25.6 MET*session/week, p=0.0007) compared to girls regardless of age. The relationship between sex and LPA was changed as subjects grew older; the rate of decrease in LPA was greater in boys than girls with age (Figure 4.2.8 in Appendix M).

Figure 4.2.1

Total PA and Age by Puberty

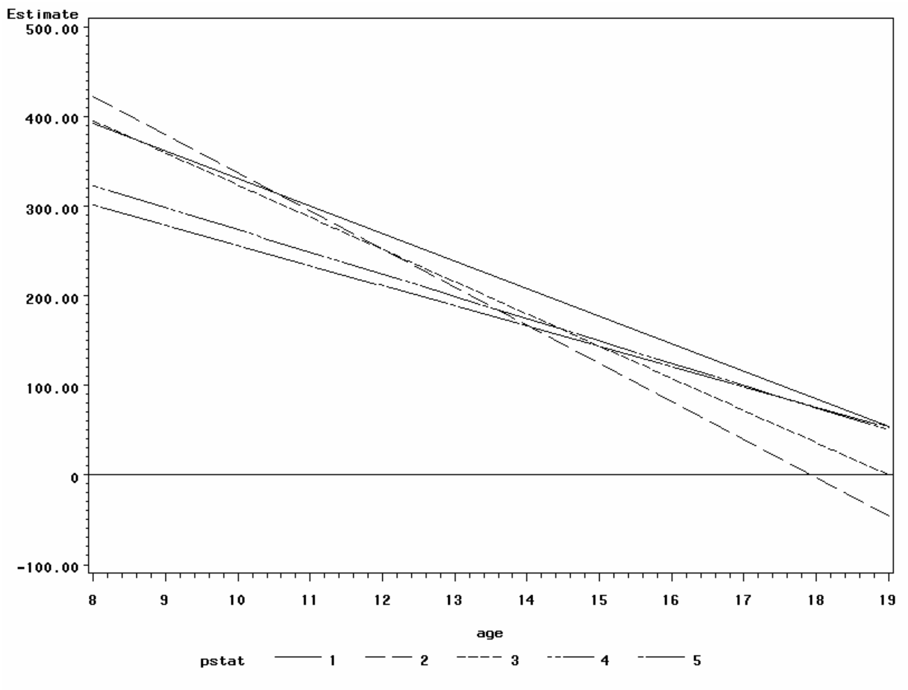
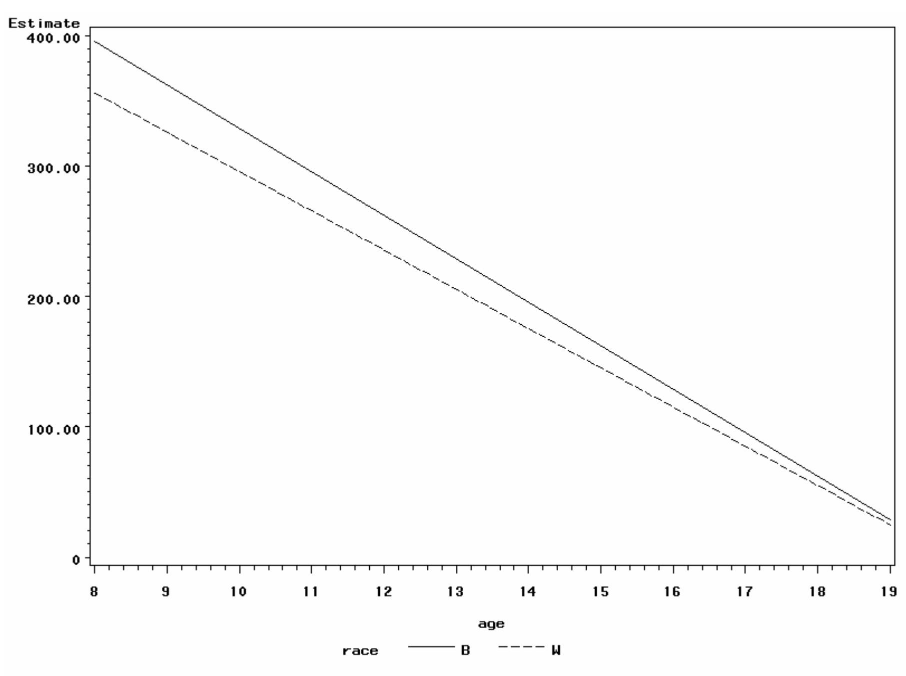


Figure 4.2.2

Total PA and Age by Race



Race showed significant main and interaction effects with age on total PA (Figure 4.2.2), MPA and VPA (Figures 4.2.9 to 4.2.10 in Appendix M). While younger black children had higher scores in total PA, MPA and VPA, the gap between black and white became diminished with age due to more rapid drop of activity scores in black subjects as they became older. LPA score was significantly higher in black youth than white youth as much as 9 MET*session/week (p=0.0012) with no interaction with age.

Family income showed significant main effects for total PA (p=0.015) and VPA scores (p=0.023) and no main and interaction effects for LPA and MPA. However, results could not be interpreted in a meaningful direction (total PA score for the group 1, 2, 3, & 4: 13.0., -16.2, -53.8, 0; VPA for the group 1, 2, 3, & 4: 6.2, -13.2, -33.2, 0).

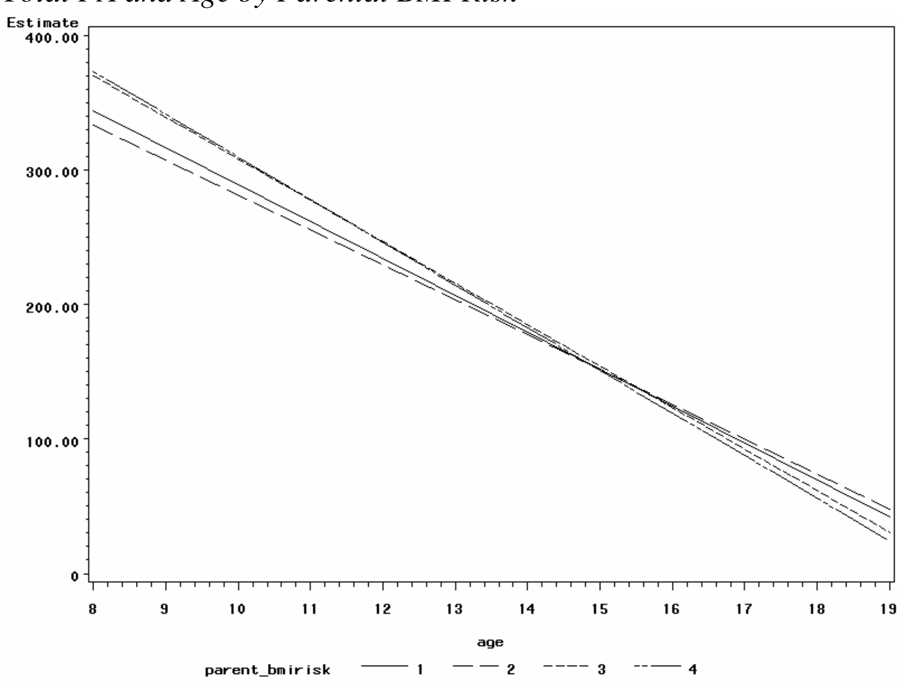
Parental education had significant main and interaction effects with age on total PA, MPA, and VPA scores but no main or interaction effects on LPA scores. Similar to family income, it was difficult to interpret results in a meaningful direction as shown in Figures 4.2.11 to 4.2.13 (Appendix M).

Parental activity showed small but significant main effects on total PA (p=0.05) regardless of age. Total PA score of children was 30.3 (parental activity group 1), 55.9 (parental activity group 2), 39.3 MET*session/week (parental activity group 3) higher than that of children from the highest parental activity group (group 4). That is, children from the highest parental activity group (group 4) had the lowest total PA score compared to others. Parental activity had also significant main and interaction effects with age on VPA. In other words, although VPA score of younger children was lower in the highest parent activity group (group 4), as subjects grew older, the rate of decrease in VPA was slower in children from the highest parental activity group compared to ones from the lower parental activity groups (group 1, 2, and 3) (Figure 4.2.14 in Appendix M).

Parental BMI risk had significant main and interaction effects with age on total PA (Figure 4.1.3), LPA, MPA, and VPA scores (Figures 4.2.15 to 4.2.17 in Appendix M): p for main effects 0.0001 (LPA), 0.0003 (MPA), 0.0178 (VPA), and 0.0001 (total PA) and p for interaction effects 0.0007 (LPA), 0.0015 (MPA), 0.0223 (VPA), and 0.0004 (total PA). Figures 4.2.3 shows that children from the lower parental BMI risk groups (group 1 & 2) had lower total PA scores when they were young, but the decrease of activity scores was slower than ones from the higher parental BMI risk groups (group 3 & 4: BMI 30 or greater).

Figure 4.2.3

Total PA and Age by Parental BMI Risk



Models with Child Variables

When models included child variables (puberty, sex, race, and interaction terms with age) to predict each PA score, significant main and interaction effects of puberty with age on all PA scores were found (Table 4.3.1 in Appendix M). All PA scores decreased with age and the velocity of decrease was greater at pubertal stages 1, 2, and 3 than at stages 4 and 5, which was the same result as seen with bivariate relationships. Sex had significant longitudinal relationships to total PA, MPA, and VPA scores (Figure 4.2.18 to 4.2.20 in Appendix M), as all 3 PA scores decreased faster in girls than boys as they grew. Thus, a distinctive difference between boys and girls seems to be found in older ages in total PA, MPA, and VPA but not in LPA. The relationship between race and activity scores was similar to the bivariate relationship: black youth had significantly higher LPA (8.4 MET*session/week) and MPA (10 MET*session/week) scores compared to white youth regardless of age. Total PA and VPA were also higher in young black children but decreased faster with age compared to white ones.

Full Models

Models with child and parental variables showed significant effects of puberty, sex, race, family income, parental education, and parent BMI risk on physical activity scores across age (Table 4.3.2 in Appendix M).

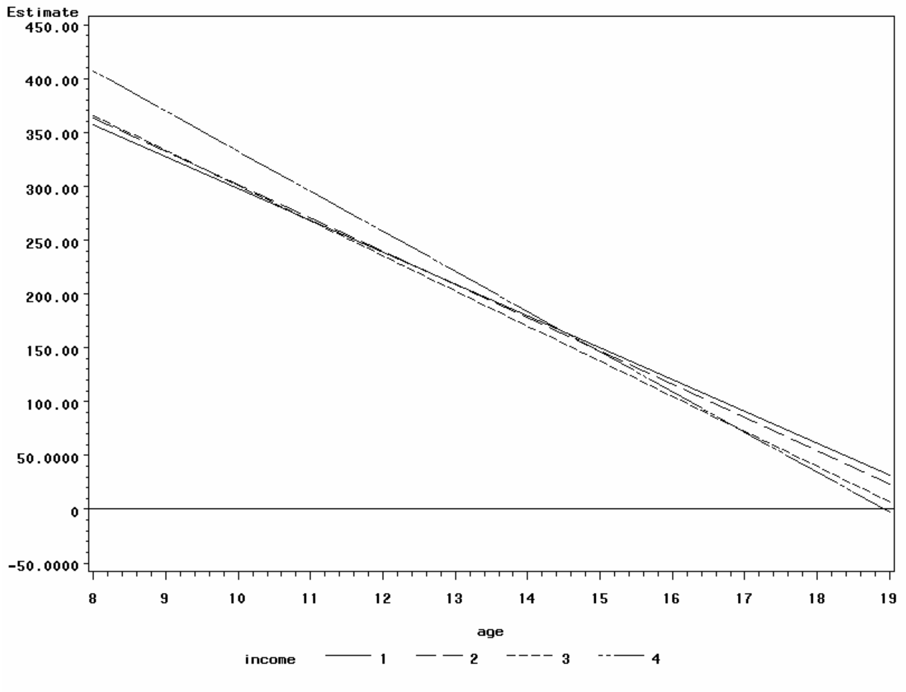
Final (Reduced) Models

Only significant variables (with p value less than 0.05) were included in final models

Table 4.3.3 shows results from final models. All PA scores decreased with age. Puberty had significant main and interaction effects for all PA scores, similar to results from bivariate relationship (Figure 4.2.1) or models with child variables. Sex had significant main and interaction effects only for MPA. Girls had higher MPA scores than boys when they were young. As subjects grew older, the rate of decrease in MPA was greater in girls than boys (Figure 4.2.21 in Appendix M). Results from race were similar to the bivariate relationship. Black had higher PA scores in all activity variables in younger children but decreased more rapidly with age than white (Figure 4.2.2). Family income showed significant main and interaction effects for total PA, LPA, and VPA. Children from the highest income level (group 4) had the highest PA scores when they were young but the decreasing rate of PA was faster compared to ones from the lower income family (group 1, 2, and 3) (Figure 4.2.4 for total PA, Figures 4.2.22 and 4.2.23 for LPA and VPA). Parental education also had significant main and interaction effects in total PA, LPA, and VPA. However, the results could not be interpreted in a meaningful direction, similar to results from bivariate relationships. Parental activity, which was the significant variable in VPA score from the full model, became non-significant in the final model when considered with other significant child and parental variables. Parental BMI risk had significant main and interaction effects for LPA and MPA: children from the lower parental BMI risk group (group 1 & 2) had lower LPA and MPA when subjects were young, but children from the risk group 1 and 2 had slower decreasing velocity of LPA and MPA as they grew.

Figure 4.2.4

Total PA and Age by Family Income from Final Model



In sum, all PA scores decreased with age. Child variables including puberty, sex, and race showed significant longitudinal relationships to physical activity. There was a faster decrease of all PA scores at pubertal stages 1, 2, and 3 than the stages 4 and 5, a faster drop of MPA in girls than in boys, and a faster drop of all PA scores in black than in white youth. Among parental characteristics, family income and parental BMI risk were significant and meaningful variables related to PA of children across age: higher total PA, LPA, and VPA in young children from the highest income group (group 4) but a faster drop of PA scores with age in youth from the highest income group; and higher LPA and MPA in young children with the higher parental BMI (group 3 and 4) but a faster decrease of PA scores with age in subjects from the higher parental BMI risk groups.

Table 4.3.3

Predictors of Physical Activity across Age from Final Model

Outcome: Total PA score (N=5517)				LPA score (N=5517)			MPA score (N=5801)			VPA score (N=5478)		
		Estimate	SE		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		453.6	45.9	Intercept	105.7	12.1	Intercept	147.1	16.4	Intercept	216.1	28.6
Age ***		-20.8	2.9	Age ***	-4.1	0.8	Age ***	-6.8	1.0	Age ***	-10.5	1.8
Pstat ***	1	231.5	57.6	Pstat ***	66.0	13.7	Pstat ***	43.5	20.3	Pstat ***	123.2	35.8
	2	287.2	49.1		63.1	11.8		69.9	17.5		155.9	30.6
	3	163.5	42.2		54.1	10.3		38.8	15.2		75.7	26.4
	4	-2.1	39.9		18.1	9.8		-4.8	14.3		-10.4	24.9
	5	0	.		0	.		0	.		0	.
							Sex *	13.5	6.0			
								0	.			
Race ***	B	101.4	18.8	Race **	16.3	4.6	Race **	21.0	6.1	Race ***	59.1	11.8
	W	0	.		0	.		0	.		0	.
Family income *	1	-105.1	35.8	Family income **	-34.1	8.4	Family income			Family income *	-63.3	22.4
	2	-92.4	33.2		-27.0	7.8					-59.7	20.8
	3	-75.6	31.5		-19.5	7.3					-47.1	19.7
	4	0	.		0	.					0	.
parental education **	1	62.3	34.5	parental education **	14.5	8.2	parental education			parental education **	32.0	21.8
	2	93.2	23.9		17.9	5.7					50.6	15.0
	3	70.5	22.2		17.1	5.3					43.0	13.9
	4	0	.		0	.					0	.
										Parental activity	0.7	2.6
											2.4	2.4
											5.3	2.5
											0	.

Table 4.3.3 (Continued) *Predictors of Physical Activity across Age from Final Model*

Total PA score				LPA score			MPA score			VPA score		
		Estimate	SE		Estimate	SE		Estimate	SE		Estimate	SE
Parental BMI risk	1	-1.5	4.9	parental BMI risk *	-8.7	6.3	parental BMI risk *	-6.8	9.3	Parental BMI risk		
	2	-2.5	4.5		-12.0	5.7		-20.3	8.5			
	3	4.0	4.9		3.8	6.1		2.6	9.0			
	4	0	.		0	.		0	.			
Age x pstat ***	1	-15.7	4.7	Age x pstat ***	-4.6	1.1	Age x pstat ***	-3.4	1.6	Age x pstat ***	-8.0	2.9
	2	-20.9	3.5		-4.6	0.8		-5.7	1.2		-10.9	2.2
	3	-10.8	2.7		-3.8	0.7		-3.0	1.0		-4.6	1.7
	4	0.5	2.5		-1.2	0.6		0.2	0.9		1.0	1.5
	5	0	.		0	.		0	.		0	.
							Age x sex **	-1.2	0.4			
								0	.			
Age x race ***	B	-5.6	1.3	Age x race *	-0.7	0.3	Age x race **	-1.2	0.4	Age x race ***	-3.3	0.8
	W	0	.		0	.		0	.		0	.
Age x family income *	1	7.3	2.5	Age x family income **	2.5	0.6	Age x family income			Age x family income +	4.0	1.5
	2	6.2	2.3		2.0	0.5					3.6	1.4
	3	4.5	2.2		1.4	0.5					2.4	1.4
	4	0	.		0	.					0	.
Age x pt education **	1	-3.4	2.4	Age x pt education **	-1.0	0.6	Age x pt education			Age x pt education **	-1.7	1.5
	2	-6.5	1.7		-1.4	0.4					-3.6	1.0
	3	-4.8	1.5		-1.3	0.4					-2.9	1.0
	4	0	.		0	.					0	.
Age x pt BMI risk	1			Age x pt BMI risk *	0.5	0.5	Age x pt BMI risk *	0.5	0.7	Age x pt BMI risk		
	2				0.7	0.4		1.4	0.6			
	3				-0.3	0.4		-0.0	0.6			
	4				0			0				.

Note. *p<0.05, **p<0.01, ***p<0.0001 (from type 3 test of fixed effect)

Research Question 3

Question 3 was, "Do puberty, gender, race, and parental characteristics influence sedentary behaviors across age (as subjects grow older)?" The analysis was done using the same 4 steps as the question 2: (a) longitudinal bivariate relationships (how each predictor related to sedentary behaviors across age), (b) models with child variables, (c) full models including child and parental variables, and (c) final (reduced) models with only significant variables from the full model. Residual analysis was done for the final models. No pattern was found. Tables from the first 3 steps and all figures (except 4.3.1 to 4.3.2) are presented in Appendix N.

Longitudinal Bivariate Relationships

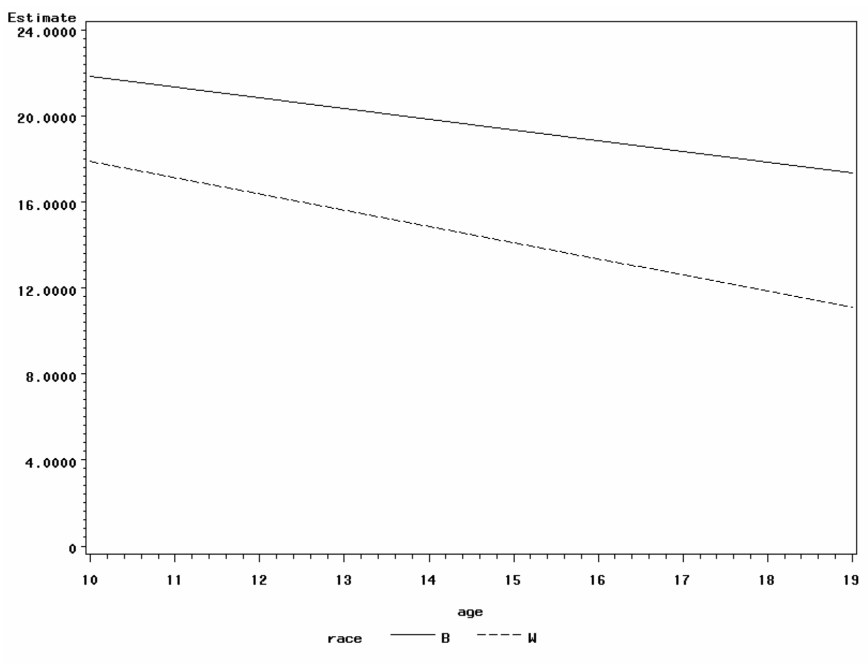
Puberty had significant main (p=0.04) and interaction effects with age (p=0.02) on TV viewing. While hours of TV viewing per week slightly increased with age at pubertal stage 1 and 2, the hours decreased with age at pubertal stage 3, 4, and 5. The decrease was faster at the stage 4 and 5 than the stage 3 (Figure 4.3.3 in Appendix N). Puberty had no significant longitudinal relationship with video games and computer use, as subjects grew older.

Sex had no significant effect on TV watching and computer use. A significant main effect of sex was found in the relationship to video games. Boys spent 1.2 hours more per week in playing video games compared to girls (p=0.0019) regardless of age.

Race showed significant interaction effect with age (p=0.0396) on TV and significant main and interaction effects with age on video games (p=0.0124); that is, the relationships between race and TV and between race and video games changed as subjects grew older. As subjects grew older, white subjects showed a slightly faster drop in hours of TV viewing than black subjects (Figure 4.3.1). Younger black children spent more time in video games than white ones but the difference between the races became smaller as they grew due to a rapid drop of playing video games in black children (Figure 4.3.2).

Figure 4.3.1

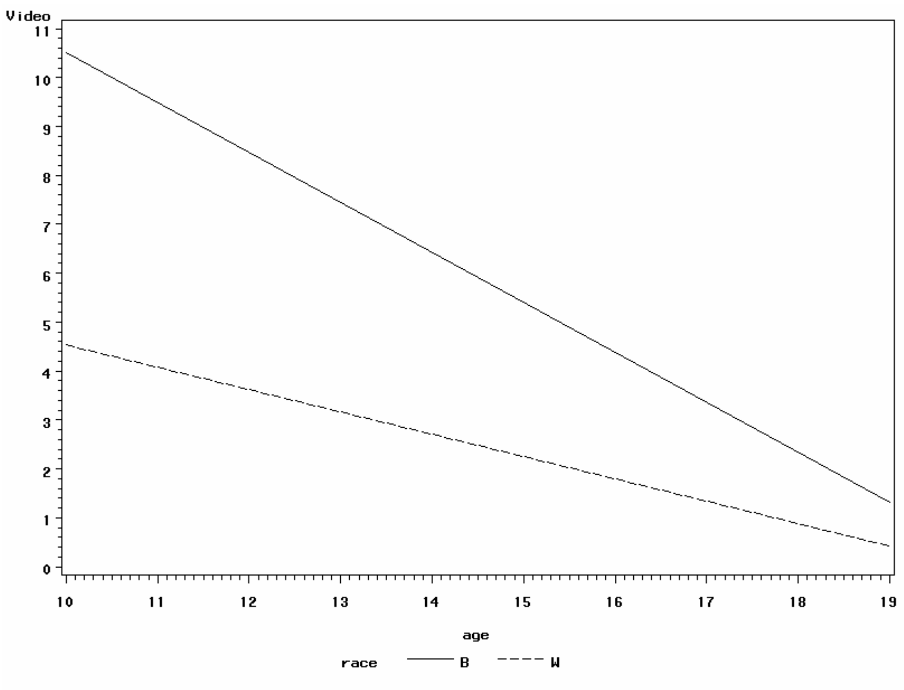
Hours of TV viewing and Age by Race



Family income had no effect on TV and computer use but significant main and interaction effects with age on video game use. Children from the higher income families spent more time in playing video games when they were young. As they grew older, differences in playing video games between children from the lower family income groups became smaller due to a rapid drop of video game use in ones from the higher income groups (Figure 4.3.4 in Appendix N).

Figure 4.3.2

Hours of Video Games and Age by Race



Parental education had no effect on hours of TV and computer use but significant main effect on video game use (p=0.0043). Children from the highest parental education group (group 4) showed the lowest time spent in playing video games (hours in video game: 2.9 for group 1, 2.6 for group 2, 1 for group 3, and 0 for group 4).

No significant effect was found in the relationship between parental activity and TV and between parental activity and computer use. However, parental activity had significant main and interaction effects with age on video game use. Subjects with more active parents (group 3 and 4) spent less time in video games when they were young, compared with subjects with less active parents (group 1 and 2) (Figure 4.3.5 in Appendix N). As time went by, the difference in video game time of children with active (group 3 and 4) and less active (group 1 and 2) parents became smaller due to a rapid decrease in hours of video game use in subjects with less active parents.

Parental BMI risk did not have significant relationship to TV, video games, and computer use.

Models with Child Variables and Final Models

When child variables (puberty, sex, and race, and interaction terms with age) were included, the interaction between race and age was the only significant term related to TV (p=0.0098) (Table 4.4.1 in Appendix N). That is, hours of TV viewing decreased faster in white than black youth. None of variables were significantly related to TV when parental variables were added (Full model, Table 4.4.2 in Appendix N). Thus, race and age were the only significant factors related to TV viewing, when child variables were considered.

When child variables were included in the model to predict hours of video game use, there were significant main and interaction effects of puberty and race (Table 4.4.1 in Appendix N). Figure 4.3.6 (Appendix N) shows the relationship between puberty and time spent in video games across age. Subjects at pubertal stage 2 and 4 showed a faster drop than ones from stage at 3 and 5. Although students at stage 1 seem to increase hours of video games with age, the trend is not reliable due to very small number of observations (only 44 subjects aged 10 to 15). The longitudinal relationship between race and video games was also significant, and was the same as bivariate relationship. That is, young black children spent more time in video games and the time spent decreased more rapidly with age. Thus, the difference between the races became smaller in older adolescents.

When all child and parental variables were included to predict hours of video games (Full model, Table 4.4.2 in Appendix N), sex, race, parental BMI risk, interaction effects between age and race and between age and parental BMI risk were significant. Table 4.4.3 shows the results from a final model. Boys spent more time (about 1.4 hours per week) in video games than girls ($p<0.0001$). Race had significant main and interaction effects with age on video games, which was similar to the results as shown in bivariate relationship (Figure 4.3.2) or models with child variables. Main and interaction effects with age of parental BMI risk were not significant in the final model.

Time spent in computer use was not significantly related to any variables when bivariate relationships, models with child variables, and full model were examined.

In sum, hours of TV viewing was explained with race and age when considering child variables; hours of TV viewing was higher in black children at the beginning and decreased faster in white than black youth, as subjects grew older. Parental characteristics did not explain TV viewing of children. Video games showed a distinctive difference between boys and girls; boys spent more time in video games than girls regardless of age. Race also influenced video games longitudinally; young black children spent more time than white ones but the difference decreased as they grew older. Video game use was not significantly related with parental characteristics when both child and parental variables were considered.

Table 4.4.3

Predictors of Square Rooted Video across Age from Final Model

Square Rooted Video N=4769		
	Estimate	SE
Intercept	3.0	0.6
Age ***	-0.1	0.04
Sex ***	-1.2	0.1
	0	.
Race ***	2.3	0.5
	0	.
Parental BMI risk	1.8	0.7
	1.2	0.6
	1.2	0.7
	0	.
Age x race **	-0.1	0.03
	0	.
Age x Parental BMI risk	-0.1	0.04
	-0.1	0.04
	-0.1	0.05
	0	.

Note. $**p<0.01$, $***p<0.0001$ (from type 3 test of Fixed effect)

Research Question 4

Question 4 was, “Are sedentary scores inversely related to MPA or VPA or total PA scores across age, when puberty, sex, race, and parental characteristics are controlled in the model? The same 4 steps were conducted to answer the question: (a) longitudinal bivariate relationships between each sedentary behavior and physical activity score, (b) longitudinal relationships between sedentary behaviors and physical activity, when controlled for child variables (models with child variables), (c) longitudinal relationships between sedentary behaviors and physical activity, when controlled for child and parental variables (full models), and (d) longitudinal relationships between sedentary behaviors and parental variable, when controlled for significant variables from the step 3 (final models). Tables from the first 3 steps and all figures (except Figure 4.4.1) are located at Appendix O.

Longitudinal Bivariate Relationships

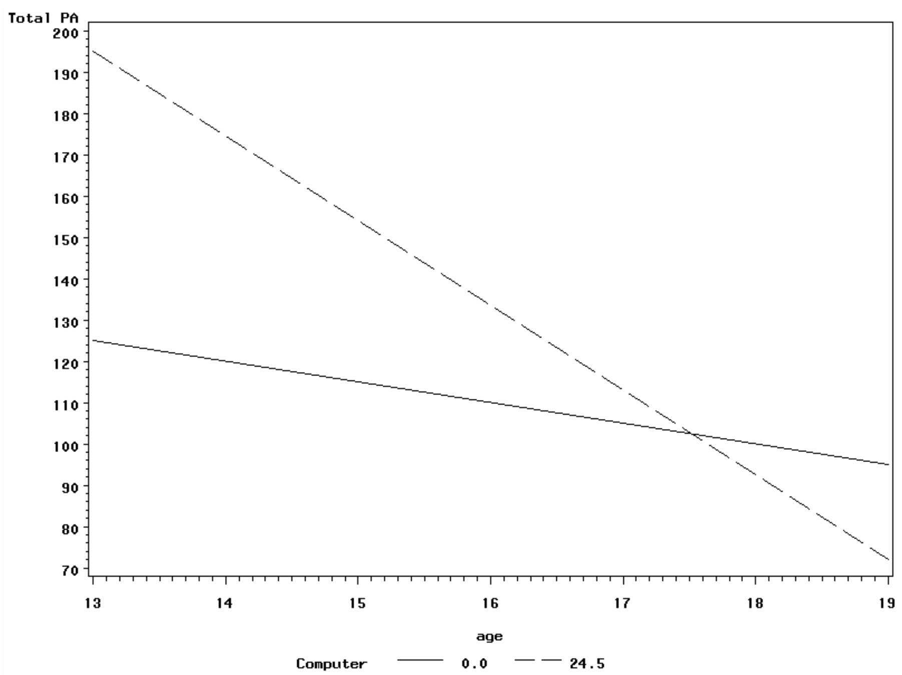
TV was not significantly related to MPA. However, TV showed significant main and interaction effects with age on VPA (Figure 4.4.2 in Appendix O). The figure 4.4.2 showed change of VPA across age when hours of TV were minimum (0 hours/week) and maximum (24.5 hours/week). That is, students who spent more time in watching TV decreased VPA faster than ones with less time spent in TV, as they grew. TV also showed significant main effects on total PA score (parameter estimator: 2.37, p=0.0459), which was expected as total PA included low level of activity including TV or video.

Hours spent on video games were not significantly related to MPA or VPA. Only video game use had a significant main effect on total PA (estimator: 2.52, p=0.022), which was also expected as described above.

Computer use was significantly associated with MPA, VPA, and total PA across age. That is, as subjects grew older, adolescents who used computers showed faster decrease in total PA (Figure 4.4.1) and MPA and VPA (Figures 4.4.3 to 4.4.4 in Appendix O).

Figure 4.4.1

Total PA and Age by Computer Use



Models with Child Variables

When all child variables were controlled for in the models, MPA, VPA, and Total PA were not significantly predicted by TV or video game use. However, computer use was significantly related to all PA scores across age, and results were similar to the bivariate relationships; PA scores were higher in adolescents who spent more time in computer use at the age 13, but ones who used a computer more often showed a more rapid decrease in MPA, VPA, and total PA from the age 13 to 19 (Tables 4.5.1 to 4.5.3 in Appendix O). Among control variables, sex had significant longitudinal effect on MPA and total PA; girls decreased MPA and total PA with age faster than boys (ages from 13 to 19).

Full Models

When all child and parental variables were in the models (full model), only computer use was significantly related to MPA, VPA, and total PA (Tables 4.5.4 to 4.5.6 in Appendix O).

Final (Reduced) Models

Parameter estimates from final models are presented in Table 4.5.7. Younger adolescents (at the age of 13) who spent more time in computer had higher MPA, VPA, and total PA scores but decreased all 3 PA scores faster with age. According to the final model, other child and parental variables were not significantly associated with PA score. Therefore, only the decreasing velocity of PA (MPA, VPA, and total PA) was inversely related to computer use from the age 13 to 19; the more computer use, the faster decrease in physical activity.

Table 4.5.7

Hours of Computer Use and Physical Activity across Age from Final Model

Outcome: MPA N=1709				VPA N=1093			Tot PA N=1093		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		73.67	15.68	Intercept	65.93	37.53	Intercept	153.20	48.74
Age **		-2.73	0.92	Age	-1.49	2.20	Age	-2.96	2.85
Computer **		3.58	1.29	Computer **	8.40	2.58	Computer *	10.48	4.13
Parental Activity	1			Parental Activity	22.06	58.27	Parental Activity	-5.08	7.19
	2				-74.74	48.61		-10.63	5.98
	3				-81.85	50.72		-0.49	6.12
	4				0	.		0	.
Computer x age **		-0.20	0.08	Computer x age **	-0.48	0.15	Computer x age *	-0.57	0.24
Parental Activity x age	1			Parental Activity x age	-1.63	3.43			
	2				4.08	2.86			
	3				4.82	2.97			
	4				0	.			

Note. *p<0.05, **p<0.01 (from type 3 test of Fixed effect)

Research Question 5

Question 5 was, "To what extend is child obesity predicted by moderate or vigorous or total PA scores across age, when puberty, gender, race, eating behavior (sweet drink intake), and parental characteristics are controlled in the model?" The same 4 steps as used in questions 2, 3, and 4 were conducted to investigate the longitudinal relationships between physical activity and obesity. The residual plots for the final models did not show any patterns. Tables from the first 3 steps and all figures (except Figures 4.5.1 to 4.5.2) are presented in Appendix P.

Longitudinal Bivariate Relationships

Each MPA, VPA, and Total PA score had significant main and interaction effects with age on all obesity variables (BMI, BMI z score, SSF and waist) (Figure 4.5.1 and 4.5.2). That is, when subjects were young, higher activity scores (MPA, VPA, and Total PA) were related to being less obese. However, as subjects grew older, the rates of obesity more rapidly increased in subjects who report being more active.

Longitudinal bivariate relationships between the control variables and obesity, which is not the focus of this question, are presented in Appendix P.

Figure 4.5.1

Obesity (BMI and BMI z) and Age by PA scores

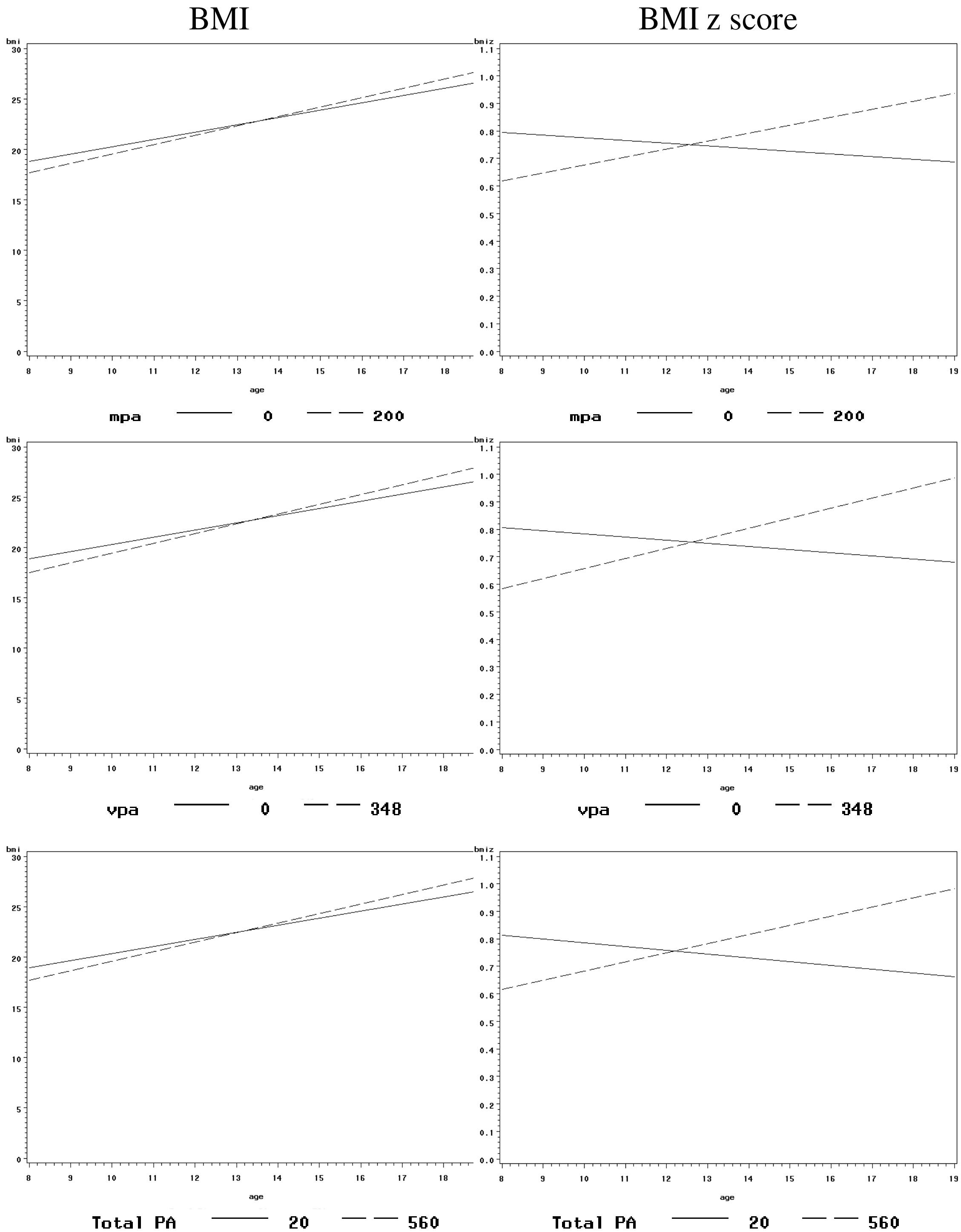
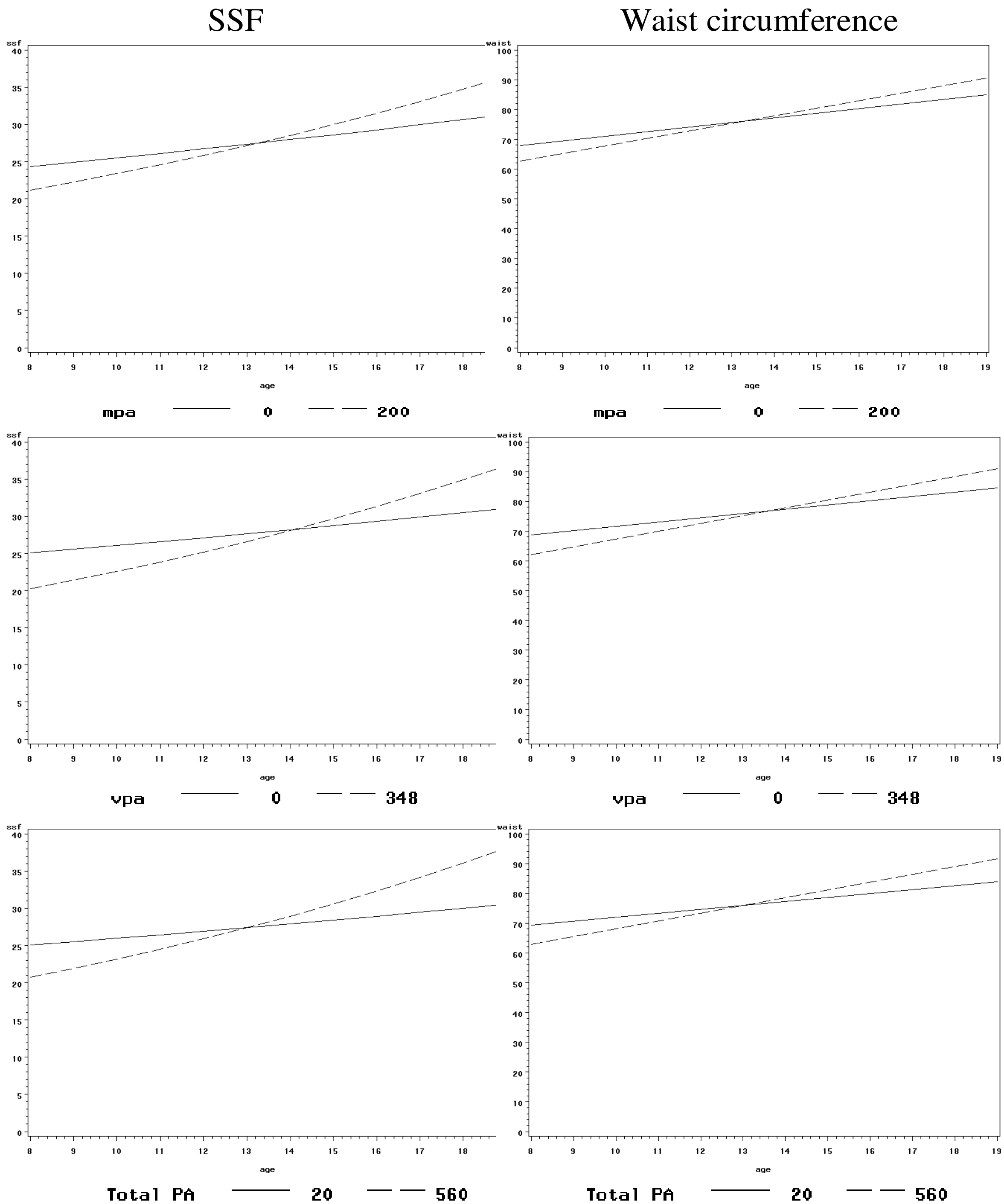


Figure 4.5.2

Obesity (SSF and Waist) and age by PA scores



Models with Child Variables

When child variables were controlled in the models, physical activity (MPA, VPA, or total PA) did not related to BMI (Table 4.6.1 in Appendix P). VPA and total PA but not MPA showed significant main and interaction effects with age in explaining BMI z score; when subjects were young, higher VPA and total PA scores were related to having a lower BMI z score (Table 4.6.2 in Appendix P). However, as subjects grew older, the increase of BMI z score was more rapid in subjects who had higher VPA and total PA scores. VPA and total PA had significant main and interaction effects on SSF; higher VPA or total PA was related to a lower SSF in younger subjects but the increase of SSF was faster in subjects with higher VPA and total PA (Table 4.6.3 in Appendix P). Waist circumference was not significantly related to physical activity variables, when controlled for child variables.

Among the control variables, puberty and race showed significant longitudinal relationships to BMI: subjects at pubertal stages 1 to 3 increased BMI faster with age compared with those at stage 4 and 5; black subjects increased BMI more rapidly compared to white ones. Puberty showed significant main and interaction effects with age to predict BMI z score, similar to BMI. In addition, race had significant main effect on BMI z score; black subjects had a higher BMI z score than white subjects (difference: 0.261-0.271) regardless of age. Puberty and sex showed significant main and interaction effects; younger girls had less SSF but as they grew older, the velocity of increase in SSF was greater in girls than in boys. Waist circumference was significantly associated with puberty and sex and interaction effects between puberty and age and between sex and age (Table 4.6.4 in

Appendix P). Boys had a lower waist circumference when they were young, but boys increased waist more rapidly with age than girls.

Full Models

Statistical significance from the full models is presented in Tables 4.6.5 to 4.6.8 (Appendix P). When both child and parental variables were controlled for in the models, physical activity scores were not significantly related to any obesity measures (BMI, BMI z, SSF, and waist).

Final (Reduced) Models

According to the final models, only puberty showed significant longitudinal relationship to BMI. Parental BMI risk had significant main effect on child BMI (child BMI for group1: -5.0, group2: -3.75, group3: -2.0, and group4: 0) (Table 4.6.9), which means that a higher parental BMI was related with a higher BMI of children. In case of BMI z score as an outcome variable, puberty had a significant longitudinal relationship and black subjects had significantly higher BMI z scores (0.28-0.29) than white ones regardless of age (Figure 4.5.3 in Appendix P). Parental BMI risk also showed significant main effect on child BMI z score (child BMI z for group 1: -0.85, group 2: -0.56, group 3: -0.24, and group 4: 0) (Table 4.6.9), which means children with more obese parents showed higher BMI z score. SSF was significantly related to age, puberty, sex, parental BMI risk, and interaction between puberty and age and between sex and age when child and parental variables were considered (Table 4.6.10). Waist circumference was significantly associated with age, puberty, and interaction between puberty and age and between sex and age (Table 4.6.10).

Therefore, while VPA and total PA scores were significantly and negatively related to BMI z score and SSF when adjusted child variables, the statistical significance disappeared after adding parental variables in the models. The strongest predictors of child obesity were parental obesity, pubertal stage, age, and gender.

Table 4.6.9

PA Scores and BMI/BMIz from Final Model

BMI N=5857				BMI z N=5857			BMIz and VPA N=5691		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		18.72	0.92	Intercept	1.70	0.20	Intercept	1.67	0.20
Age ***		0.57	0.05	Age	-0.04	0.01	Age *	-0.03	0.01
							VPA	-0.001	0.001
Pstat ***	1	-6.30	1.20	Pstat ***	-0.81	0.28	Pstat **	-0.61	0.29
	2	-4.62	1.05		-0.63	0.24		-0.37	0.25
	3	-3.91	0.94		-0.68	0.21		-0.6	0.21
	4	-1.30	0.85		-0.14	0.19		-0.13	0.19
	5	0	.		0	.		0	.
Sex	F			Sex			Sex		
	M								
Race	B			Race ***	0.29	0.05	Race ***	0.28	0.05
	W				0	.		0	.
Parental BMI risk ***	1	-5.0	0.34	Parental BMI risk ***	-0.85	0.07	Parental BMI risk ***	-0.84	0.07
	2	-3.75	0.31		-0.56	0.06		-0.55	0.06
	3	-2.0	0.34		-0.24	0.07		-0.24	0.07
	4	0	.		0	.		0	.
							Age x VPA	0.0001	0.00004
Age x pstat ***	1	0.47	0.10	Age x pstat **	0.05	0.02	Age x pstat **	0.03	0.02
	2	0.31	0.07		0.04	0.02		0.02	0.02
	3	0.25	0.06		0.04	0.01		0.04	0.01
	4	0.08	0.05		0.01	0.01		0.01	0.01
	5	0	.		0	.		0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Table 4.6.10

PA Scores and Log(SSF)/Waist from Final Model

SSF N=5835				Waist N=2359		
		Estimate	SE		Estimate	SE
Intercept		3.68	0.14	Intercept	66.06	5.75
Age ***		-0.02	0.01	Age ***	1.03	0.34
Pstat ***	1	-0.78	0.19	Pstat ***	-24.40	6.33
	2	-0.49	0.16		-26.87	5.97
	3	-0.06	0.14		-14.75	5.55
	4	-0.15	0.13		-5.73	5.40
	5	0	.		0	.
Sex ***	F	-0.3	0.07	Sex	3.51	2.59
	M	0	.		0	.
Parental BMI risk ***	1	-0.39	0.03			
	2	-0.28	0.03			
	3	-0.13	0.03			
	4	0	.			
Age x pstat ***	1	0.06	0.01	Age x pstat ***	1.75	0.46
	2	0.04	0.01		2.01	0.40
	3	-0.001	0.01		0.98	0.34
	4	0.01	0.01		0.29	0.32
	5	0	.		0	.
Age x sex ***	F	0.04	0.01	Age x sex *	-0.40	0.18
	M	0	.		0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Research Question 6

Question 6 was, “To what extent is child obesity predicted by sedentary behaviors across age, when puberty, gender, race, sweet drink intake, and parental characteristics, are controlled in the model? The same 4 steps as used in questions 2 to 5 were done to answer the question 6. Residual analysis for the final models did not show any patterns. Tables from the first 3 steps and all figures (except Figure 4.6.1) are presented in Appendix Q.

Longitudinal Bivariate Relationships

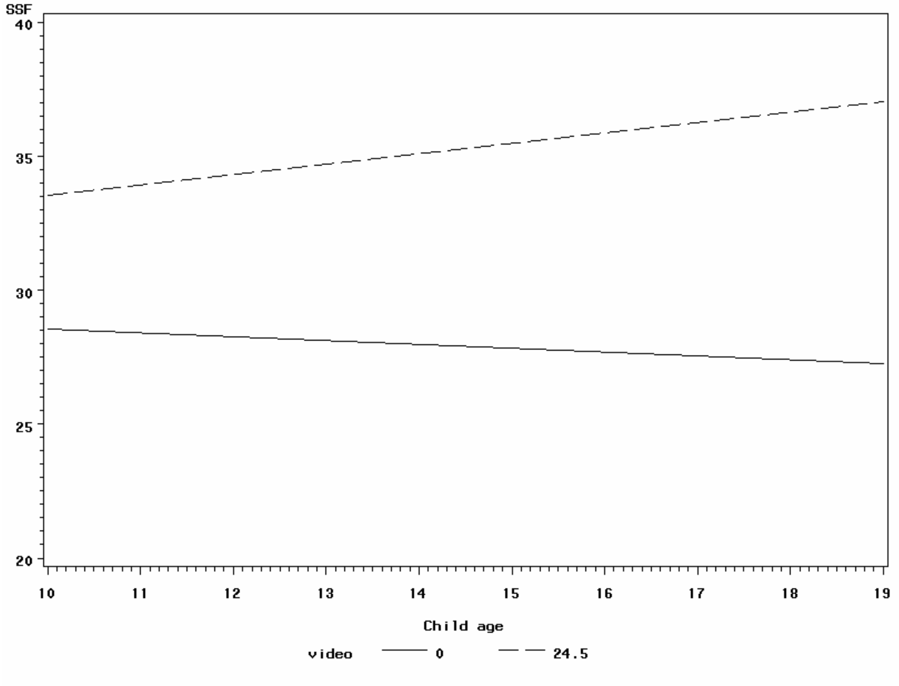
TV and computer use had no significant main and interaction effects on any obesity indicators. Only hours of video games showed a significant interaction effect with age on BMI and significant main and interaction effects with age on BMI z score (Figures 4.6.2 and 4.6.3 in Appendix Q). That is, as adolescents grew older, subjects spending more time in video games gained BMI and BMI z score slightly faster than others.

Models with Child Variables

In the models controlling for child variables, no obesity indicators (BMI, BMI z, SSF, and waist) were explained by hours of TV viewing and computer use (Table 4.7.1 to 4.7.4 in Appendix Q). Only the interaction between video games and age on log-transformed SSF was significant (Table 4.7.3 in Appendix Q). That is, while children spending more time in video games gained SSF with age, those spending less time in video games increased SSF more slowly with age (Figure 4.6.1).

Figure 4.6.1

SSF and Age by Hours of Video Games from Model with Child Variables



Full Models

When child and parental variables were controlled for, video games were significantly related to BMI z score (Table 4.7.6 in Appendix Q) and log-transformed SSF (Table 4.7.8 in Appendix Q).

Final (Reduced) Models

When only significant variables from the full model were controlled for, log-transformed SSF was significantly related to video game use and the interaction between video and age (Table 4.7.11). That is, adolescents who spent more time in video games had greater SSF and gained SSF faster with age compared to others with less time playing video games. Among control variables, parental BMI risk, sex, race, and family income had also significant main and interaction effects on SSF. In other final models including all child and parental variables, significant relationships between sedentary behaviors and obesity was not found. In short, BMI was explained only by puberty and the interaction between age and puberty (Table 4.7.9). BMI z score was significantly related to puberty, parental education, parental BMI risk, and interaction between puberty and age (Table 4.7.10). Table 4.7.12 presents predictors of waist circumference from final model. Nothing was significant.

In summary, only hours spent in playing video games were significantly and positively related to SSF when adjusted child variable and parental variables in subjects aged 10 to 19. Adolescents who spent more time in playing video games had greater SSF and also showed faster increase of SSF as they grew older.

Table 4.7.9

Predictors of BMI from Final Model

BMI (N=8598)			
		Estimate	SE
Intercept		14.64	0.75
Age ***		0.63	0.04
Pstat ***	1	-5.05	0.91
	2	-4.00	0.82
	3	-3.03	0.74
	4	-0.47	0.69
	5	0	.
Age x pstat ***	1	0.37	0.07
	2	0.27	0.06
	3	0.20	0.05
	4	0.03	0.04
	5	0	.

Note. *** $p<0.0001$

Table 4.7.10

Predictors of BMI z score from Final Models

BMI z (N=5838)		BIC: 9329.2		N=4498	BIC: 7311.4	
		Estimate	SE		Estimate	SE
Intercept		1.73	0.21	Intercept	1.83	0.23
Age		-0.03	0.01	Age	-0.04	0.01
				Video	-0.01	0.01
Pstat ***	1	-0.74	0.28	Pstat ***	-0.68	0.92
	2	-0.60	0.24		-0.94	0.37
	3	-0.66	0.21		-0.87	0.24
	4	-0.13	0.19		-0.07	0.20
	5	0	.		0	.
	F			Sex	-0.04	0.04
	M				0	.
Parental education **	1	0.24	0.07	Parental education **	0.30	0.08
	2	0.16	0.05		0.17	0.06
	3	0.05	0.05		0.07	0.06
	4	0	.		0	.
Parental BMI risk ***	1	-0.91	0.07	Parental BMI risk ***	-0.93	0.07
	2	-0.61	0.06		-0.60	0.07
	3	-0.26	0.07		-0.31	0.08
	4	0	.		0	.
				Age x Video	0.001	0.0005
Age x pstat *	1	0.04	0.02	Age x pstat ***	0.04	0.07
	2	0.03	0.02		0.05	0.03
	3	0.04	0.01		0.05	0.02
	4	0.01	0.01		0.002	0.01
	5	0	.		0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Table 4.7.11

Predictors of Log (SSF) from Final Model

Log(SSF) (N=5637) BIC: 3176.2				Log(SSF) (N=4296) BIC=2215.4		
		Estimate	SE		Estimate	SE
Intercept		3.03	0.13	Intercept	3.01	0.19
Age *		0.02	0.01	Age	0.01	0.01
				Video **	-0.01	0.01
Sex **	F	-0.27	0.07	Sex ***	-0.39	0.09
	M	0	.		0	.
	B			Race **	0.31	0.11
	W				0	.
Family income **	1	0.43	0.14	Family income *	0.58	0.21
	2	0.35	0.13		0.50	0.2
	3	0.47	0.14		0.64	0.2
	4	0	.		0	.
Parental BMI risk ***	1	-0.39	0.03	Parental BMI risk ***	-0.37	0.04
	2	-0.27	0.03		-0.25	0.03
	3	-0.12	0.03		-0.13	0.04
	4	0	.		0	.
				Age x video **	0.001	0.0003
Age x sex ***	F	0.04	0.01	Age x sex ***	0.05	0.01
	M	0	.		0	.
				Age*race *	-0.02	0.01
					0	.
Age x family income *	1	-0.02	0.01	Age x family income *	-0.03	0.01
	2	-0.02	0.01		-0.03	0.01
	3	-0.02	0.01		-0.04	0.01
	4	0.004	0.02		0	.

Table 4.7.12

Predictors of Waist from Final Model

BMI (N=5050)			
		Estimate	SE
Intercept		46.21	1.64
Age		2.24	0.10
Sex	F	5.30	1.75
	M	0	.
Age x sex	F	-0.47	0.13
	M	0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Research Question 7

Question 7 was, “Is there an interaction between physical activity and sedentary behavior and obesity across age when puberty, gender, race, and parental characteristics are controlled in the model? The same 4 steps were conducted to answer the question except question 7 included interaction terms between physical activity and sedentary behaviors on obesity. Residual analysis for the final models did not show any patterns. Tables from the first 3 steps and all figures (except Figures 4.7.1 and 4.7.2) are presented in Appendix R.

Longitudinal Bivariate Relationships

A significant interaction effect between VPA and computer use on BMI (Figure 4.7.3 in Appendix R) was found, in addition to significant interaction effect between total PA and computer use on waist circumference (Figure 4.7.4 in Appendix R). That is, while adolescents who had higher VPA score had lower BMI, those who had spent more time in computer use had a more beneficial effect of VPA on having a lower BMI. Similarly, students who spent more time using computers showed a beneficial effect of total PA on smaller waist circumference.

Models with Child Variables

When child variables were controlled in the models, only the significant interaction was between MPA and computer on log-transformed SSF (Table 4.8.1 in Appendix R). There was a beneficial effect of MPA to having lower SSF and the effect was stronger in adolescents who spent more time in computer (Figure 4.7.1).

Full Models

After controlling for all child and parental variables, the only significant interaction between physical activity and sedentary behaviors was between video game use and VPA on log-transformed SSF.

Final (Reduced) Models

Table 4.8.2 shows parameter estimates from the final model. Figure 4.7.2 shows that students with higher VPA had lower SSF but those who spent more time in video games did not have the beneficial effect of VPA on lower SSF.

Figure 4.7.1

SSF and MPA by Computer Use from Model with Child Variables

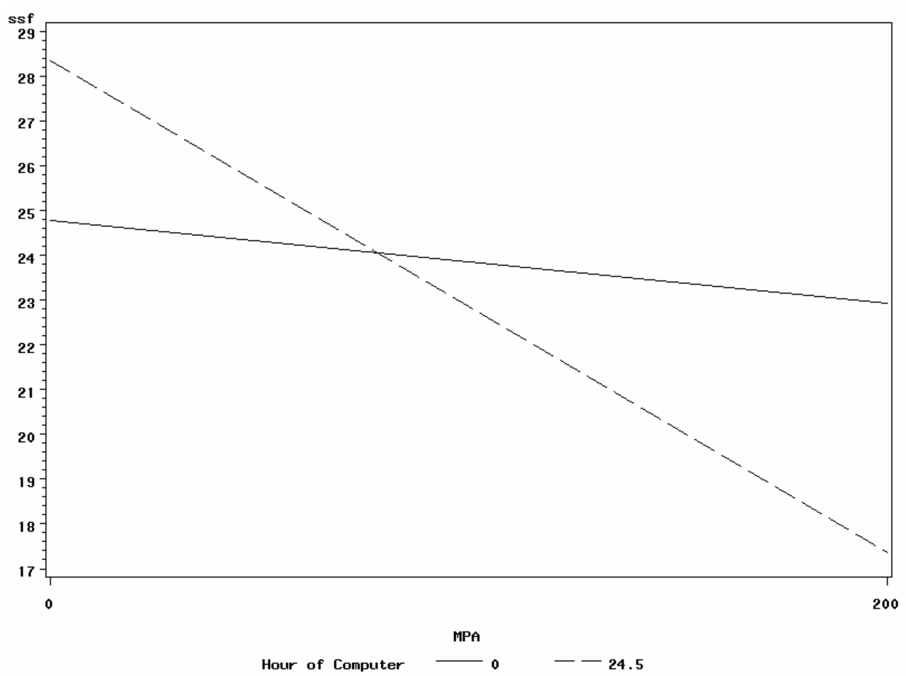
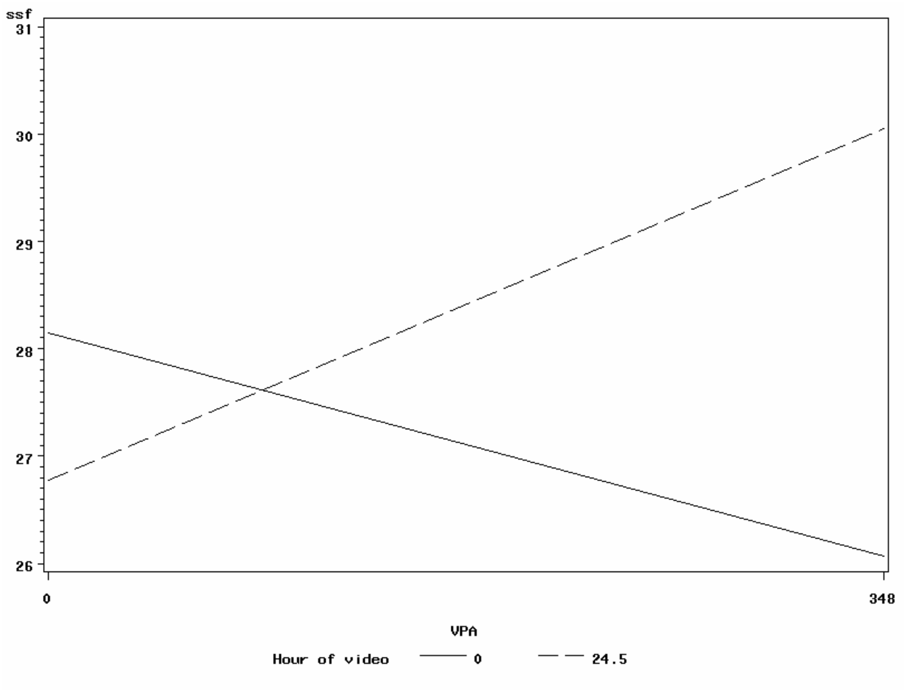


Figure 4.7.2

SSF and VPA by Video Games from Final Model



In sum, when controlled for only child variables, computer use (sedentary behavior) changed the relationship between MPA and SSF. When controlled for child and parental variables, video game and VPA showed a significant interaction effect on SSF. Although the more computer use strengthened the beneficial effect of MPA on lower SSF, spending more time in video games was associated with having greater SSF regardless of the level of VPA.

Table 4.8.2

Interaction between VPA and Video on Log(SSF) from Final Model

Log(SSF) N=4230			
		Estimate	SE
Intercept		3.54	0.10
Age		-0.02	0.01
VPA		-0.0002	0.0001
Video **		-0.02	0.01
VPA*video *		0.00002	0.00001
Sex ***	F	-0.37	0.09
	M	0	.
Race	B	0.03	0.03
	W	0	.
Family Income **	1	0.15	0.05
	2	0.09	0.05
	3	0.08	0.05
	4	0	.
Parental BMI risk ***	1	-0.37	0.04
	2	-0.25	0.03
	3	-0.13	0.04
	4	0	.
Video x age **		0.001	0.0004
Sex x age ***	F	0.05	0.01
	M	0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Summary

According to the population trajectories, self-reported PA scores (total PA, LPA, MPA, and VPA) decreased with age (from 8 to 19 years). Obesity (BMI, SSF, and waist) increased with age (from 8 to 19 years). BMI z score increased from the age of 8 to 14 years and slightly decreased from the age of 14 to 19 years. While physical activity decreased, sedentary behaviors (TV and video games) also decreased from the ages of around 12 to 18 years. No trend was found in computer use.

Physical activity was longitudinally related to child variables (puberty, sex, and race) in addition to parental variables (family income and parental BMI risk). On the other hand, sedentary behaviors were not significantly related to parental characteristics. Instead, longitudinal changes of TV and video games were significantly explained by child variables: race for TV and sex and race for video games. Computer use was not explained by any child or parental variables. In addition, physical activity and sedentary behaviors were not inversely related except the relationship between computer use and physical activity; while greater hours spent in computer use was related to higher physical activity at the age of 13 years, the more computer use, the faster decrease in physical activity as subjects grew older (from the age of 13 to 19 years).

When controlling for child variables, VPA and total PA (physical activity) were significantly related to lower BMI z score and SSF (obesity) when subjects were young. This became non-significant after adding parental variables. Therefore, in this study child obesity seems to be explained more by parental obesity than by child physical activity. As for the relationships between sedentary behaviors and obesity, only video game play was significantly and positively related to SSF (obesity) after controlling for child and parental variables.

Interestingly, there were significant interaction effects between sedentary behaviors and physical activity on obesity: there was an interaction between computer and MPA on SSF when adjusted for child variable and an interaction between video games and VPA on SSF when controlled for child and parental variables. Computer use and video games seem to have different effects on the relationships between physical activity and obesity; while computer use strengthened the beneficial effect of MPA on having lower SSF, video game play nullified the beneficial effect of VPA on having lower SSF.

CHAPTER 5

DISCUSSION

This study examined: (a) trajectories of physical activity, sedentary behaviors, and obesity across age, (b) longitudinal relationships between predictors (child and parental characteristics) and health behaviors (physical activity and sedentary behaviors), (c) longitudinal relationships between obesity and health behaviors (physical activity and sedentary behaviors) when controlled for important covariates, and (d) the interaction between physical activity and sedentary behaviors on obesity in the sample of elementary to high school cohorts in rural North Carolina. Developmental science perspective provided the conceptual framework for this longitudinal study. A mixed model method was employed for analyses in order to examine longitudinal relationships (changes across age). This chapter presents discussion of the major findings, comparisons of the results with previous studies, limitations, suggestions for future studies, and clinical implications.

Major Findings

The findings of the current study provide evidence for changes in physical activity, sedentary behaviors, and obesity as children and adolescents grow older. That is, physical activity decreased and obesity, as measured by BMI, sum of skinfold thickness, and waist circumference increased from the age of 8 to 19 years. From the age of 10 to 13 years, a faster decrease in physical activity was accompanied by a rapid increase in obesity. While physical activity decreased, sedentary behaviors (hours of TV viewing and video game play) also decreased from around 12 to 18 years of age. Computer use did not show any trend by age.

Longitudinal changes in physical activity were significantly related to some child characteristics (puberty, sex, race), and to two family characteristics (family income and parental BMI risk), as follows:

Puberty: a faster decrease of all PA scores at the pubertal stages of 1, 2, and 3 than the stages of 4 and 5;

Gender: a faster drop of physical activity in girls than boys;

Race: higher physical activity in young black children but a faster decrease with age in black youth than in white youth;

Family economics: higher physical activity in young children from the highest income family but a faster drop of physical activity with age in youth from the highest income family;

Parental BMI: higher physical activity in young children with the higher parental BMI but a faster drop of physical activity with age in youth with the higher parental BMI.

On the other hand, sedentary behaviors (hours of TV viewing, video games, and computer use) were not significantly explained by parental characteristics. Longitudinal changes of hours of TV viewing were explained by the interaction between race and age; black youth watched TV more than white youth and hours of TV viewing decreased faster with age in white youth. Video game use significantly differed by gender as well as by the interaction between race and age; boys spent more time in video games regardless of age; black youth spent more time in video game play but decreased faster in time spent on video games in black than white youth as they grew older. Longitudinal changes of computer use were not explained by child and parental characteristics.

Interestingly, computer use was positively related to physical activity at the age of 13 years but decreasing velocity of physical activity with age was faster in subjects with more computer use from the age of 13 to 19 years. That is, the more computer use, the faster decrease in physical activity as subjects grew older. Other sedentary behaviors (TV viewing and computer use) were not significantly related to longitudinal changes of physical activity.

Although physical activity (VPA and total PA) was significantly related to some measures of obesity (BMI z score and SSF), when controlled for child variables, the significance disappeared after adding parental variables; parental obesity seemed to be the strongest correlate to child obesity. As for sedentary behaviors, only hours of video game use were positively related to longitudinal changes of SSF when adjusted for child and parental variables in subjects aged 10 to 19 years; that is, adolescents who spent more time in video games had greater SSF and gained SSF faster as they grew older.

Another interesting result is the significant interaction effects between sedentary behaviors and physical activity on obesity. There were significant interactions between computer use and moderate physical activity on SSF when controlled for child variables and between video games and vigorous physical activity on SSF when controlled for child and parental variables. However, the direction of interaction was different; spending more time in computer use strengthened the beneficial effect of moderate physical activity on having lower SSF, while spending more time in playing video games nullified the beneficial effect of vigorous physical activity on having lower SSF.

Trajectories of Physical Activity, Sedentary Behaviors, and Obesity

Self-reported physical activity (LPA, MPA, VPA, and total PA) significantly decreased from the age of 8 to 19 years. As speculated, these findings are similar to those of previous studies (Brodersen et al., 2007; Duncan et al., 2007; Kimm et al., 2002; Nelson et al., 2006). In particular, the velocity of decrease in activity differed across age; a rapid decrease was found between the age of 10 to 12 years (31% decrease in VPA and 21% in LPA & MPA). Additionally, differences emerged in activities with different intensity; vigorous physical activity (VPA) decreased greater from the age of 8 to 12 years (50% decrease) than moderate physical activity (MPA) and low physical activity (LPA) (37% decrease respectively). A faster or greater decrease in vigorous activity can also be found in the literature (Duncan et al., 2007; Sherar et al., 2007). These results suggest that the age of 10 to 12 years is a critical period for physical activity interventions and also that maintaining vigorous physical activity through those years is an important focus for interventions.

Trajectories of sedentary behaviors showed a slight decrease in hours of TV viewing from the age of 13 to 17 years (decreased about 3 hours per week) and a decrease in hours of video games from the age of 12 to 18 years (diminished about 2.7 hours per week). Relatively few researchers have examined trends in sedentary behaviors across age. Decreasing trends in TV and video games are in line with the previous studies. Summed hours spent on TV and video viewing decreased only for girls in 5-year follow-up study among 806 middle school students aged 11 to 15 at baseline (Nelson et al., 2006). Similarly, girls, but not boys, showed slightly decreasing prevalence of watching TV more than 1 hour per day from the age of 11 to 13 years (Villard et al., 2007). A cross-sectional analysis of a nationally representative sample of more than 14,000 US adolescents also showed that summed hours of TV, video, and computer game decreased with increasing age (12-15 years: 23.1, 16-17 years: 20.3 and 18-22 years: 19.8) (Gordon-Larsen et al., 1999). On the other hand, a group of researchers reported an increasing trend with age in sedentary behaviors (summed hours of TV, video, and computer use). In a 5-year follow-up study in the British samples aged 11 to 12 years at baseline, there was a 2.5 hours per week increase for boys and a 2.8 hours per week increase for girls (Brodersen et al., 2007). To compare the results from their study and the current study, an additional analysis was done using summed hours of TV, video games, and computer use in a subsample of our subjects aged 13 to 19. The results showed that summed hours of the 3 sedentary behaviors decreased with age, which is similar to the results from Gordon-Larsen and colleagues (1999) but differs from the report of Brodersen and associates.

No trend by age was found in computer use. Only 2 studies were found related to trajectory of computer use across age and the results are conflicting. While computer use increased for boys with age in high school students (Nelson et al., 2006), a decreasing trend was found for both genders in Swedish subjects from the age of 11 to 13 years (Villard et al., 2007). Hence, the limited number of studies indicates that more research is needed to understand how computer use changes as children mature.

It is unclear why sedentary behaviors decreased as subject grew older, in parallel with decrease of physical activity (LPA, MPA, VPA, and total PA). In the current study low intensity activity decreased with age. The low intensity activity (LPA) variable was derived by multiplying the frequency per week and corresponding METs of TV or VCR movies and video games as well as other low intensity activities (i.e., art and crafts, bowling, collecting stamps, rocks, group meetings or club meetings, gymnastics, homework, music lessons, reading, and walking). Self-reported sedentary behaviors, either measured with frequency or hours spent on those behaviors, seem to decrease with age. A few possible reasons for the decrease in low intensity activity can be speculated. One possible reason is that physical activity behaviors and sedentary behaviors are independent events. Or, as mentioned in previous studies that parents tend to underreport hours of TV viewing of their children (Cheng et al., 2004; Dietz & Strasburger, 1991), adolescents may underreport their time spent on watching TV, in that they become more aware of socially desirable behaviors, as they mature. Another possibility is that as subjects grow older, they may engage more in different types of sedentary behaviors that were not captured in the questionnaire. For example, instead of TV viewing and video game play, they may spend more time talking over the phone with friends. Therefore, further research about the magnitude of underreporting of screen time and about time spent in different types of sedentary behaviors (other than screen time) as children grow older will be required for clearer understanding about these issues.

Obesity (BMI, SSF, and waist circumference) increased with age. Similar to physical activity, the increasing rate of obesity differed by age with a more rapid increase in younger children and slower increase in older adolescents. In particular, increasing trends in BMI and waist circumference were very similar, which is consistent with the literature (Berkey & Colditz, 2007; Dai et al., 2002; Hlaing et al., 2001; Wardle et al., 2006). SSF increased from the age of 8 to 13 years then flattened. Gender differences may be the reason for the flattened growth after the age of 13 years. According to the National Heart, Lung, and Blood Institute's Growth and Health Study (NGHS), SSF increased from the ages of 9-10 to 18-19 years among 1152 black and 1135 white girls (Kimm et al., 2005). This was the same in the study of Heude et al. (2006). However, SSF for boys increased from the age of 5 to 11 years then decreased until the age of 17 years in their study.

Unlike BMI and waist circumference, BMI z score showed a different trajectory across age. BMI z score increased from the age of 8 to 14 years and decreased until the age of 19 years. The use of BMI z score in longitudinal studies is controversial. Some researchers argue that BMI z score is calculated from cross-sectional samples (Ogden et al., 2002), so using BMI z score for longitudinal changes is problematic (Berkey & Colditz, 2007). Others address that BMI z score is appropriated to use in longitudinal studies to examine changes of body fat. Hunt et al. (2007) suggest that decrease in BMI z score of 0.5 over 6 months or 0.6

over 6 to 12 months corresponds to fat loss (measured by bioimpedance). Hence, based on the study of Hunt et al., although BMI z score increased from the age of 8 to 14 years (0.577 to 0.764) and decreased from the ages of 14 to 19 years (0.764 to 0.606), these changes were over a much longer time. Thus it is not sufficient to interpret as significant fat changes during maturation.

Predictors of Longitudinal Changes of Physical Activity

When child and parental variables were included, pubertal maturation was significantly related to longitudinal changes of physical activity, in addition to a significant decrease of physical activity with age. That is, there was a faster decrease of all PA scores at the pubertal stages of 1, 2, and 3 than the stages of 4 and 5, which is similar to the results of Riddoch and associates (2007b) and is also consistent with the decrease by age. A faster drop of physical activity in girls than in boys is also consistent with previous studies (Armstrong et al., 2000; 2007; Lasheras et al., 2001; Lindquist et al., 1999; Riddoch et al., 2007b).

As for racial differences, the current study found higher physical activity in young black children in addition to a faster drop of all PA scores with age in black youth than in white youth, which is similar to some studies (Kimm et al., 2002; Ku et al., 2000). However, results from many previous studies regarding racial differences in activity are not consistent with this finding from the current study. Indeed, the literature shows conflicting results. While some researchers have reported higher physical activity in white children and adolescents than in black youth (Gordon-Larsen et al., 2000; O'Loughlin, Paradis, Kishchuk, Barnett, & Renaud, 1999; Schmitz et al., 2002), other studies have presented no significant difference between white and black youth (Lindquist et al., 1999; Neumark-Sztainer et al., 2003; Sallis, Prochaska et al., 1999). Hence, further studies will be needed to understand the influence of race on changes in activity over time.

Among parental characteristics, family income and parental BMI risk were significantly related to longitudinal changes of child physical activity. Young children from the highest family income group showed the highest physical activity level, which can be found in the literature (Gordon-Larsen et al., 2000; Lasheras et al., 2001; Starfield et al., 2002; Tuinstra et al., 1998). However, children from the highest family income group decreased physical activity faster with age, which suggests that as subjects grow older, the influence of parental SES may fade away. Children with obese parents (either mother or father's BMI equal to 30 or greater) showed higher physical activity when they were young. However, the children with obese parents decreased in physical activity faster than children with less obese parents as they grew older. Only 3 studies on the relationship between parental obesity and child activity were examined; while no significant relationship between parental obesity and child obesity was found in prepubertal girls (Treuth et al., 2000), significant and negative associations between parental obesity and child activity were found among preschoolers (Eck et al., 1992; Klesges et al., 1990). It is not suitable to compare the results from the present study and the previous studies due to different ages of the sample. Therefore, how the relationships between parental obesity and child activity change as youth grow also needs to be examined in future studies.

These results about determinants of physical activity across age provide detailed information regarding interventions targeting physical activity. The rapid drop of activity at the pubertal stages of 1, 2, and 3 presents a need for early intervention to prevent a fall in activity level. Gender and race specific approaches will also be needed due to a faster decrease of activity in girls than in boys and in black subjects than in white subjects. This indicates that black girls may need the most intense interventions. While young children from lower income families comprise one vulnerable population, older children from high income families also need to be considered as target populations for physical activity interventions due to a rapid drop of physical activity in those subjects. In addition, measures to prevent a rapid drop in physical activity will be required for children and adolescents who have obese parents.

Predictors of Longitudinal Changes of Sedentary Behaviors

When adjusted for child variables, only race showed significant longitudinal relationships to hours of TV viewing. Time spent in front of TV was lower in white youth than black youth and decreased faster in white youth than black youth, which is in line with the literature (Brodersen et al., 2007; Brodersen et al., 2005; Gordon-Larsen et al., 1999; Schmitz et al., 2002). When the model included child and parental variables, none of variables were significantly related to longitudinal changes of TV viewing. One previous multivariate analysis of cross-sectional study showed very similar findings that gender, race, age, pubertal development were not significantly related to hours of TV viewing (Lindquist et al., 1999). Having only one parent in the home was the only significant factor for TV viewing in their study.

When child and parental variables were included in the model, video game use was significantly related to sex regardless of age. Boys spent more time in video games than girls. Similar results can be found in the literature (Gordon-Larsen et al., 1999, 2000). In addition, race showed significant longitudinal relationships with video game use. Younger black children spent more time in video games but decreased rapidly with age. Similarly, Schmitz et al. (2002) reported that black subjects played video games more than white ones among 3798 adolescents aged 11 to 15.

Time spent in computer use was not significantly related to any variables and this author could not find studies about determinants of computer use in children or adolescents.

Comparison of Predictors for Physical Activity and Sedentary Behaviors

Results showed that child variables and some parental variables explained longitudinal changes of physical activity as noted above. However, sedentary behaviors were not explained by parental characteristics. Similar results can be found in previous research. According to Schmitz et al. (2002), while physical activity was significantly related to parental education (the higher education of parents, the more active the children), sedentary behaviors (TV and video games) were only significantly related to race. Thus, different determinants of physical activity and sedentary behaviors need to be considered for interventions.

Relationships between Physical Activity and Sedentary Behaviors

Computer use was significantly related to physical activity scores across age; physical activity score were higher at the age of 13 years in adolescents who spent more time in computer use. Similar results can be found in the literature (Koezuka et al., 2006; Santos et al., 2005; Utter et al., 2003). Although it is unclear why computer use, a sedentary behavior, is positively related to physical activity, Santos and associates (2005) provided a possible reason that computer use, unlike TV, is not a passive tool. Koezuka and colleagues (2006) suggested that, in boys, computer use is a protective factor against physical inactivity

However, from longitudinal relationships, adolescents who spent more time with computers showed a more rapid decrease in moderate, vigorous, and total physical activity from the age of 13 to 19 years. The present study adds to existing knowledge by showing negative longitudinal relationships between physical activity and computer use; subjects with more computer use decreased faster in physical activity (MPA, VPA, and total PA) from the age of 13 to 19 years. That is, the more use of computer, the faster decrease in physical activity after age 13.

TV and video games were not significantly related to longitudinal changes of moderate, vigorous, and total physical activity in the current study. Non-significant relationships between sedentary behaviors and physical activity can be found in many studies (Allision, 2002; Brodersen et al., 2005; Ekelund et al., 2006; Grund et al., 2001; Katzmarzyk et al., 1998; Lindquist et al., 1999; Parsons et al., 2005; Utter et al., 2003). Additionally, a longitudinal study also showed a non-significant relationship between TV and physical activity (moderate to vigorous physical activity and vigorous activity) over time in a Canadian sample (Neumark-Sztainer et al., 2003) and between TV and moderate to vigorous physical activity in the US sample (Taveras et al., 2007). Although many studies also reported significant negative relationships between TV viewing and physical activity (Janssen, Katzmarzyk, Boyce et al., 2004; Marshall et al., 2004; Strauss et al., 2001), the results from the current study are not totally out of line as Marshall et al. presented an effect size between physical activity and sedentary behaviors as -0.096, which is very low.

Unlike the non-significant longitudinal relationship between TV and video game use and physical activity, the significant positive longitudinal relationship between computer use and physical activity reveals that computer use may have different characteristics from TV viewing and video game use, which was also found in the study of Santos et al. (2005). These results indicate that using summed hours of sedentary behaviors (TV, video games, and computer use), which has been frequently done by many researchers, may mask some important relationships or differences.

The finding that hours of TV viewing and video game play were not inversely associated with physical activity support a theory that physical activity and sedentary behaviors (TV and video games) may not in the same continuum of level of activity but rather are in two different dimensions. If physical activity and sedentary behaviors are not two ends of one continuum, then children and adolescents can be both physically very active and engage in a fairly high amount of sedentary behaviors. In particular, some researchers have reported that subjects who spent more time in sedentary behaviors can also be physically active. According to Lowry et al. (2002), who studied a representative sample of high school students grades 9 to 12 in the National Youth Behavior Survey (N=15,349), viewing TV more than 2 hours a day was related to greater participation in physical activity among black males, but not in white males and females and black females. In a study of subjects from 9 countries (N=12,538) boys who spent more time on TV and computer use participated in more physical activity (te Velde et al., 2007). Hence, subjects can be either (a) highly active and highly sedentary, (b) highly active and less sedentary, (c) less active and highly sedentary, or (d) less active and less sedentary. This may raise a question that how obesity is related to health risk behaviors with 2 different dimensions; that is, a question about interaction between physical activity and sedentary behaviors on obesity. This issue will be discussed later.

Longitudinal Relationships between Physical Activity and Obesity

Physical activity scores (MPA, VPA, and total PA) showed significant longitudinal bivariate relationships to obesity (BMI, BMI z, SSF, and waist) in younger subects; higher physical activity scores were associated with being obese. These results are in line with previous studies in which no covariates was adjusted (Abbott & Davies, 2004; E. J. Ball et al., 2001; Dencker et al., 2006; Eisenmann et al., 2002; Tremblay & Willms, 2003). But, as subjects grew older, the rate of obesity increased more rapidly in subjects with higher PA scores. These results may possibly be due to over-reporting physical activity in subjects who are obese. The tendency to over-report physical activity in questionnaires has been found in previous studies, particularly in less active or obese adults (Jakicic et al., 1998; Lichtman et al., 1992). Although no empirical study has been done about over-report issue in physical activity self-report among adolescent populations, the problem of over-report tendency due to social desirability has been suspected in the literature in samples of adolescent populations (Deforche et al., 2003).

After controlling for child variables (puberty, gender, race, and interaction terms with age), vigorous and total physical activities, but not moderate physical activity, were significantly related to BMI z score and SSF; when subjects were young, higher vigorous and total physical activities were significantly associated with greater BMI z score and SSF. Since total PA score included scores from vigorous activities, the results manifest that vigorous physical activity, but not moderate activity, has beneficial effects on obesity. In line with these results, many previous studies found a significant effect of vigorous physical activity on lower obesity (Abbott & Davies, 2004; Eisenmann et al., 2002; Ness et al., 2007; Patric et al., 2004; Ruiz et al., 2006). In addition, moderate to vigorous physical activity, which includes vigorous activity, has also shown significant negative relationships to obesity (Adkins, Sherwood, Story, & Davis, 2004; Ekelund et al., 2004; Strong et al., 2005). Hence, maintaining or elevating the level of vigorous physical activity would be more effective on preventing and managing obesity in children and adolescents than just increasing moderate physical activity,

However, when adding parental characteristics in the models with child variables, the significant effect of VPA and total PA disappeared. It seems that parental BMI had a stronger influence on child obesity than the physical activity of the children. These results are consistent with results from previous research in that when parental BMI was included, physical activity became non-significant (Maffeis et al., 1998) or that physical activity was significant but explained a very small amount of the variance in obesity (Ekelund et al., 2004). Another interesting point is that while obesity increased with age, puberty also had its own explained variance of longitudinal changes in all obesity indicators in the models with parental obesity. These results can add important details on obesity interventions. Parental obesity, which can be a reflection of genetic influence, should be the first factor to be considered when planning an obesity intervention. Early prevention for obesity needs to be done not only for chronologically young children but for older children or young adolescents who are less mature in terms of puberty.

Longitudinal Relationship between Sedentary Behaviors and Obesity

From bivariate relationships, hours of video games showed significant longitudinal associations with BMI and BMI z score; as adolescents grew older (from the age of 10 to 19 years), subjects spending more time in video games gained BMI and BMI z score slightly faster than others. These are similar to results from other studies (Crooks, 2000; Tremblay & Willms, 2003). After controlling for child and parental variables, significant longitudinal relationships between video games and SSF were found; that is, adolescents who spent more time in video games had greater SSF and gained SSF faster with age compared to others with less time in playing video games. Similar results can be found. Although it was not exactly video game use, playing electronic games more than 1 hour per day was significantly related to obesity in a nationally representative sample of Portuguese (Carvalhal et al., 2007). A significant difference in video and computer game play between obese and non-obese children was reported by Crooks (2000).

The non-significant relationships between obesity and both TV viewing and computer use found in this study are consistent with the literature. Many researchers have reported that TV and computer use are not significantly related to obesity (Carvalhal et al., 2007; Giammattei et al., 2003; Hernandez et al., 1999; Proctor et al., 2003; Robinson et al., 1993; Vandewater et al., 2004; Wolf et al., 1993). Additionally, summed screen time (TV, video tapes, and video games) was not significantly related to longitudinal changes of obesity with or without controlling for parental obesity (Must et al., 2007). Although some studies have found significant relationships between TV viewing and obesity, the effects on obesity were relatively small. A very small portion of variance in obesity explained by TV viewing has been reported, such as less than 1% variance in BMI (Wake et al., 2003). One study reported that hours of TV viewing was significantly related to obesity, but the significance disappeared when parental obesity was included (Ekelund et al., 2006). Significant findings were mostly from categorical data analyses or comparison of hours of TV viewing in normal and obese children and adolescents (Gomez et al., 2007; Janssen, Katzmarzyk, Boyce et al., 2004; Lowry et al., 2002; Tremblay & Willms, 2003).

Therefore, the significant positive association between video games and obesity and non-significant association between TV viewing and obesity show that watching TV and playing video games may have different values in terms of obesity. These results differ from the results from Harrell and associates (2005), in which energy expenditure of TV viewing (age adjusted metabolic equivalents: 1.02-1.06) was lower than video games (age adjusted metabolic equivalents: 1.22-1.28 when sitting while playing and 1.45-1.47 while standing) in children and adolescents. However, both results indicate that TV viewing and video games may have different characteristics. Thus, using separate variables for TV viewing and video games, instead of summed score as a measure of sedentary behaviors in obesity research may provide more specific information.

Interaction between Physical Activity and Sedentary Behaviors on Obesity

This is the first study to examine interactions between physical activity and sedentary behaviors on obesity. When controlled for child variables, there were significant interactions between moderate physical activity and computer use on SSF. In other words, while higher moderate physical activity was related to having lower SSF, this beneficial effect was stronger in adolescents who spent more time in computer use. After controlling for all child and parental variables, there was a significant interaction between vigorous physical activity and video game use on SSF. The result is somewhat different from the interaction between computer use and activity. That is, while higher vigorous physical activity was associated with having lower SSF, this beneficial effect disappeared in subjects with greater time spent in video games. These results suggest that computer use and video game play have different characteristics. More importantly, it indicates that in spite of being physical active, if subjects spend greater time in video games, the subjects have higher risk for being obese because those subjects do not appear to have the beneficial effects of physical activity on lowering obesity. In the current study, it was not possible to compare the magnitude of risk for being obese among 4 different groups (i.e., being active and highly sedentary, being active and less sedentary, being less active and highly sedentary, and being less active and less sedentary).

Further studies on comparisons of odds ratios among 4 such groups will help to understand which group is the most vulnerable for being obese.

Limitations

The current study has several limitations. First, because this study is a secondary data analysis, the selection of variables was limited. In particular, psychological influences on health behaviors and obesity could not be assessed. For instance, self-efficacy has been reported as one of the strongest psychological variables related to physical activity (Allision, 2002; Trost et al., 1999a), but it was not measured in the CHIC study. In addition, peer influence, which is particularly important for adolescent populations, on physical activity, could not be examined.

Measurement issue is another limitation related to the internal validity of the results. Physical activity and sedentary behaviors were measured using self-report. Although the questionnaire method is the only possible and feasible option in this large population study under the restricted budget, measurement error is the most serious shortcoming. In particular, under- or over-report may contaminate the results of this study.

Third, regarding different time periods of data collection in different cohorts, cohort effects and history of life events may influence the results. That is, this study included multiple cohorts and data were collected in 1990's for cohort 1&2 and in 2000 and 2001 for cohort 4 and 5. Additionally, cohort 4 consisted of high school students and cohort 5 was elementary school students, which means cohort 4 and 5 subjects may have experienced different life history, in spite of the same period of data collection. This author tried to adjust cohort effects and life history in analyses, but there was multicolinearity between cohort and puberty. Hence, it was impossible to adjust cohort effects in the models.

Fourth, missing information about sedentary behaviors (measured as hours spent in each sedentary behavior) in cohort 5 prevented the author from examining trajectories of sedentary behaviors in elementary school children. In addition, the extensive missing information in parental characteristics, almost 40 % of missing, may have reduced the power to detect significant results.

Lastly, generalization of these results, which is related to external validity, may be restricted. The sample of this study included children and adolescents from rural North Carolina and black subjects were intentionally over-sampled. It is not a representative sample of the US youth. Hence, it is not suitable for generalization to the US populations.

Recommendations for Further Research

From the results of the current study, several recommendations for future studies can be suggested. If indeed, physical activity and sedentary behaviors are in different dimensions, and given the significant interaction effects between sedentary behaviors and physical activity on obesity, studies about how risks for obesity differ by different combinations of physical activity and sedentary behaviors will provide more comprehensive information regarding the relationships between obesity and health behaviors.

The approach of measuring duration of physical activity would also help to assess effects of physical activity on obesity in a different perspective. Because physical activity was measured only by frequency per week in this study, it was impossible to distinguish whether the activity was done in short or long bouts. Additionally, if sedentary behaviors as well as physical activity are measured on a time basis, such as with a daily activity log, it may also give an idea about what specific kinds of activities adolescents engage more in, while physical activity is decreasing.

As for measurement, it is suspected that less active and more obese subjects under-report in hours of sedentary behaviors and over-report time spent in physical activity. Researchers have investigated under-report or over-report in adult populations but not in child and adolescent populations. Thus, it is necessary to compare objective and self-report measures of physical activity and sedentary behaviors to assess the magnitude of under- and over-report.

Lastly, as noted in the limitations of the current study, further research is needed to investigate the extent of peer influences and psychological effects on health behaviors and obesity across age.

Implications for Clinical Practice

This study has several implications for interventions related to health behaviors and obesity. First, the findings provide evidence that physical activity rapidly falls during the ages of 10 to 13 years. Thus, nurse researchers and clinicians need to be aware that children in those ages are the critical periods for intervening activity level. In doing so, maintaining or increasing the level of vigorous physical activity is particularly important, since vigorous activity decreases faster than moderate and low intensity physical activity. Therefore, in clinical level, health care providers should pay attention to the level of vigorous physical activity when assessing physical activity of obese children. In the macro level approach, school is very useful environment to increase or maintain vigorous physical activity for healthy or obese youth because most children attend school and school can provide opportunities for being active through school PE. Adding more vigorous activity in the PE curriculum for late elementary and middle school student is one way to prevent a rapid drop in vigorous physical activity.

Second, based on the results that longitudinal changes of obesity are explained more strongly by pubertal maturation and parental obesity rather than physical activity, not only chronological age but pubertal maturation needs to be considered when selecting target populations for intervention, since early and mid puberty are the periods of rapidly increasing obesity. In addition, it is particularly important to aware that childhood and adolescent obesity is closely related to parental obesity; children with obese parents are more obese than ones with non-obese parents; children with obese parents become fatter more rapidly as they grow older, compared to ones with non-obese parents. Hence, nurses and clinicians should pay extra attention to young children with obese parents before they become morbidly obese. Parental participation in interventions for child obesity is also important because the association between parental and child obesity may be due to shared familial environments as well as genetic inheritance. Therefore, to correct an unhealthy familial environment, more active parental involvement for increasing physical activity, which is a correctable risk factors, is required.

Third, having acknowledged different predictors for physical activity and sedentary behaviors across age, nurse researcher and clinicians need to aware of the determinants for each health behaviors in order to successfully intervene. If lowering sedentary behaviors (TV and video game use) is the intention of interventions, gender- and race- specific approach will be effective, since black youth spend more time in TV and video game than their white counterparts and boys spend more time in video games than girls. On the other hand, for physical activity intervention, parental characteristics as well as child variables need to be assessed in that there is a faster drop of physical activity with age in youth from the highest income family and in adolescents with obese parents.

Last but most importantly, nurses and health care professionals need to understand that low physical activity and being sedentary, which are well-known risk factors for obesity, are not in the extreme at the same continuum of activity; physical activity and sedentary behaviors seem to be different functions. Therefore, interventions focusing on one behavior over the other may not be effective for every youth, in that children can be active and sedentary at the same time. For instance, this study shows that even though subjects are physically highly active, if the subjects spend greater time in video games, they do not have the beneficial effect of physical activity on lowering obesity. In this case, interventions focusing on increasing physical activity would not be effective for those subjects. Instead, replacement of sedentary behaviors (video game use) into physical activity will be more effective. Thus, assessment of risk factors in multiple aspects at an individual level is needed for effective obesity interventions.

Conclusions

Compared to existing studies, the current study can be characterized as a comprehensive longitudinal descriptive study in a very large sample. This is the first study to examine interaction effects between physical activity and sedentary behaviors on obesity. There are significant interactions; while TV viewing does not have an interaction with physical activity on obesity, video games and computer use shows significant interactions with physical activity on obesity. However, the direction of the interaction is different. That is, adolescents more computer use had a strengthened beneficial effect of physical activity on lowering obesity compared to adolescents with less computer use. However subjects with more video game play had no beneficial effect of physical activity on lowering obesity, in spite of being highly active. Thus, for prevention and management of obesity, assessing both physical activity and sedentary behaviors of each subject is critically important.

The findings also suggest that young adolescence, in particular, the age of 10 to 12 years, is a transitional period from active to less active with a more rapid decrease in vigorous activity compared to low and moderate intensity activities. Hence, timely appropriate intervention will be needed. Increasing trends in obesity indicators paralleled the decrease in physical activity across age. Sedentary behaviors (TV and video game play) also decreased across age, but computer use did not show any trend.

As for obesity, higher vigorous physical activity, not moderate activity, seems to be related to being less obese. However, obesity is explained more strongly by parental obesity and pubertal maturation than physical activity. The fact that puberty has significance in explaining obesity, in addition to age, reveals that puberty needs to be considered as an important covariate for obesity research. In addition, parental obesity should be factored in obesity interventions for children and adolescents.

Longitudinal changes of physical activity and sedentary behaviors are predicted by different variables; while physical activity is significantly related to child and parent variables, sedentary behaviors were not explained by parental characteristics. In addition, each sedentary behavior (TV, video games, computer use) seems to have different characteristics, in that computer use, not TV and video games, shows significant association with physical activity and also that only video game use is significantly related to obesity; the more video game playing, the more obese and the faster increase of obesity. Thus, use of summed hours of three behaviors as a variable of sedentary behaviors need to be cautious in future studies.

The findings of the current study may help nurse researchers and health care professionals understand how health behaviors (physical activity and sedentary behaviors) and obesity differ by child and parental characteristics as well as a developmental process. In addition, the findings that physical activity and sedentary behaviors are not in the same dimension strengthen the need for further research aimed at assessing how different combinations of physical activity and sedentary behaviors influence obesity. At the same time, it indicates the need for an evaluation of both behaviors at an individual level for the assessment of risk for obesity.

APPENDICES

APPENDIX A: The Habitual Physical Activity Subscale from the Youth Health Survey (Middle School Version: Cohort 1&2)

1. For each activity listed below, check how many times you spent more than 15 minutes doing it this past week

	TIMES THIS PAST WEEK			
	Not at all	1 or 2 times	3 to 5 times	6 or more
Aerobics or cheerleading	________	________	________	________
Arts and crafts (draw, paint)	________	________	________	________
Baseball or softball	________	________	________	________
Basketball	________	________	________	________
Bicycling	________	________	________	________
Bowling	________	________	________	________
Collecting (stamps, rocks, cards)	________	________	________	________
Dancing	________	________	________	________
Football	________	________	________	________
Group meetings or club meetings	________	________	________	________
Gym class (PE)	________	________	________	________
Gymnastics	________	________	________	________
Hanging out at the mall	________	________	________	________
Hiking	________	________	________	________
Homework	________	________	________	________
Housework	________	________	________	________
Jumping Rope	________	________	________	________
Karate or Judo	________	________	________	________
Music Lessons (choir, band)	________	________	________	________
Reading	________	________	________	________
Roller-skating or In-line skating	________	________	________	________
Running	________	________	________	________
Soccer	________	________	________	________
Skate Boarding	________	________	________	________
Swimming	________	________	________	________
Tennis	________	________	________	________
Television or VCR movies	________	________	________	________
Video Games	________	________	________	________
Walking	________	________	________	________
Yardwork or Farmwork	________	________	________	________

APPENDIX B: The Habitual Physical Activity Subscale from the Youth Health Survey (Middle and High School Version: Cohort 3 & 4)

1. For each activity listed below, circle one answer that is closest to how many times you **spent more than 15 minutes** doing it THIS PAST WEEK.

	TIMES THIS PAST WEEK			
Aerobics or cheerleading	0	1 – 2	3 – 5	6+
Arts and crafts (draw, paint)	0	1 – 2	3 – 5	6+
Baseball or softball	0	1 – 2	3 – 5	6+
Basketball	0	1 – 2	3 – 5	6+
Bicycling	0	1 – 2	3 – 5	6+
Bowling	0	1 – 2	3 – 5	6+
Collecting (stamps, rocks, cards)	0	1 – 2	3 – 5	6+
Dancing	0	1 – 2	3 – 5	6+
Football	0	1 – 2	3 – 5	6+
Group meetings or club meetings	0	1 - 2	3 – 5	6+
Gym class (PE)	0	1 - 2	3 – 5	6+
Gymnastics	0	1 - 2	3 – 5	6+
Hanging out at the mall	0	1 - 2	3 – 5	6+
Hiking	0	1 - 2	3 – 5	6+
Homework	0	1 - 2	3 – 5	6+
Housework	0	1 - 2	3 – 5	6+
Jumping Rope	0	1 - 2	3 – 5	6+
Karate or Judo	0	1 - 2	3 – 5	6+
Music Lessons (choir, band)	0	1 - 2	3 – 5	6+
Reading	0	1 - 2	3 – 5	6+
Roller-skating or In-line skating	0	1 - 2	3 – 5	6+
Running	0	1 - 2	3 – 5	6+
Soccer	0	1 - 2	3 – 5	6+
Skate Boarding	0	1 - 2	3 – 5	6+
Swimming	0	1 - 2	3 – 5	6+
Talking on the phone	0	1 - 2	3 – 5	6+
Tennis	0	1 - 2	3 – 5	6+
Television or VCR movies	0	1 - 2	3 – 5	6+
Trampoline jumping	0	1 - 2	3 – 5	6+
Video Games	0	1 - 2	3 – 5	6+
Walking	0	1 - 2	3 – 5	6+
Yardwork or Farmwork	0	1 - 2	3 – 5	6+

APPENDIX C: The Habitual Physical Activity Subscale from the Youth Health Survey (Elementary School Version: Cohort 5)

1. For each activity please circle how often you do it.

Aerobics/Cheerleading	never	not much	**sometimes**	**a lot**
Arts and Crafts (draw, paint)	never	not much	**sometimes**	**a lot**
Baseball or softball	never	not much	**sometimes**	**a lot**
Basketball	never	not much	**sometimes**	**a lot**
Bicycling	never	not much	**sometimes**	**a lot**
Bowling	never	not much	**sometimes**	**a lot**
Cleaning around the house	never	not much	**sometimes**	**a lot**
Collecting (stamps, rocks, cards)	never	not much	**sometimes**	**a lot**
Dancing	never	not much	**sometimes**	**a lot**
Football	never	not much	**sometimes**	**a lot**
Group Activities or Clubs	never	not much	**sometimes**	**a lot**
Gym Class (PE)	never	not much	**sometimes**	**a lot**
Gymnastics	never	not much	**sometimes**	**a lot**
Homework	never	not much	**sometimes**	**a lot**
Jumping Rope	never	not much	**sometimes**	**a lot**
Karate or Tae Kwon Do	never	not much	**sometimes**	**a lot**
Music Lessons or choir or band	never	not much	**sometimes**	**a lot**
Reading	never	not much	**sometimes**	**a lot**
Roller-skating	never	not much	**sometimes**	**a lot**
Running	never	not much	**sometimes**	**a lot**
Soccer	never	not much	**sometimes**	**a lot**
Skate Boarding	never	not much	**sometimes**	**a lot**
Swimming	never	not much	**sometimes**	**a lot**

Tennis	never not much **sometimes** **a lot**
TV or VCR movies	never not much **sometimes** **a lot**
Trampoline jumping	never not much **sometimes** **a lot**
Video Games	never not much **sometimes** **a lot**
Walking	never not much **sometimes** **a lot**
Yardwork or Farmwork	never not much **sometimes** **a lot**

APPENDIX D: Sedentary Behavior Questions from the Youth Health Survey (Middle School Version: Cohort 1, 2, & 3)

6. Currently, how long **EACH day** do you usually watch TV?

SCHOOL DAYS (choose ONE)

_____Never

_____Less than 1 hour

_____1 to less than 2 hours

_____2 to less than 3 hours

_____3 or more hours

NON-SCHOOL DAYS (choose ONE)

_____Never

_____Less than 1 hour

_____1 to less than 2 hours

_____2 to less than 3 hours

_____3 or more hours

8. Currently, how long **EACH day** do you usually play video games?

SCHOOL DAYS (choose ONE)

_____Never

_____Less than 1 hour

_____1 to less than 2 hours

_____2 to less than 3 hours

_____3 or more hours

NON-SCHOOL DAYS (choose ONE)

_____Never

_____Less than 1 hour

_____1 to less than 2 hours

_____2 to less than 3 hours

_____3 or more hours

APPENDIX E: Sedentary Behavior Questions from the Youth Health Survey (High School Version: Cohort 4)

11. Currently, how long **EACH day** do you usually watch TV?

SCHOOL DAYS (choose ONE)

_____Never

_____Less than 1 hour

_____1 to less than 2 hours

_____2 to less than 3 hours

_____3 or more hours

NON-SCHOOL DAYS (choose ONE)

_____Never

_____Less than 1 hour

_____1 to less than 2 hours

_____2 to less than 3 hours

_____3 or more hours

13. Currently, how long **EACH day** do you usually play video games?

SCHOOL DAYS (choose ONE)

_____Never

_____Less than 1 hour

_____1 to less than 2 hours

_____2 to less than 3 hours

_____3 or more hours

NON-SCHOOL DAYS (choose ONE)

_____Never

_____Less than 1 hour

_____1 to less than 2 hours

_____2 to less than 3 hours

_____3 or more hours

14. Other than for homework and video games, currently how much time **EACH day** do you usually spend on the computer?

SCHOOL DAYS (choose ONE)

_____Never use computer

_____ less than 1 hour

_____1 to less than 2 hours

_____2 to less than 3 hours

_____3 or more hours

NON-SCHOOL DAYS (choose ONE)

_____Never use computer

_____ less than 1 hour

_____1 to less than 2 hours

_____2 to less than 3 hours

_____3 or more hours

APPENDIX F: Sweet Drink Intake Questions from the Eating Habit Questionnaire (Middle & High School Version: Cohort 3 & 4)

Instructions: For each food item listed below, mark an "X" in the column which best describes how often you ate that food <u>last week</u>.

	3 or more times a day	1-2 times a day	3-6 times last week	1-2 times last week	not last week	never drink it
Regular or caffeine free regular soda (Coke, Pepsi, 7-Up, Root Beer etc)						
Fruit flavored soda (Sunkist Orange, Welch's Grape, Cherry, etc)						
Kool-Aid, Hawaiian Punch, Hi-C, Tropicana Twisters						

APPENDIX G: Sweet Drink Intake Questions from the Eating Habit Questionnaire (Elementary School Version: Cohort 5)

6. *Instructions: For each food item listed below, mark an "X" in the column which best describes how often you ate that food last week.*

	every day	almost every day	some times	not many times	not last week	never drink it
Regular or caffeine free regular soda (Coke, Pepsi, 7-Up, Root Beer etc)						
Fruit flavored soda (Sunkist Orange, Welch's Grape, Cherry, etc)						
Kool-Aid, Hawaiian Punch, Hi-C, Tropicana Twisters						

APPENDIX H: Physiological Date Sheet (Middle School Version: Cohort 1, 2, & 3)

PHYSIOLOGICAL DATA   Post-Test 3

1) Name: ________________________________

2) Date: __ __/__ __/__ __

3) Grade: _______

4) Sex (M or F): _______

5) Age (yrs): __ __

6) Height (nearest 0.5 cm) __ __ __.__

7) Weight (nearest 0.1 kg) __ __ __.__

8) Skinfolds:

Right mid-arm circumference (cm) ________

To nearest mm. Tricep 1)___ ___.___
2)___ ___.___
3)___ ___.___

Scapula 1)___ ___.___
2)___ ___.___
3)___ ___.___ Tech

Medications(what & when)____

9) Blood Pressure Cuff Size ____________ cm

(Right Arm) 1) _____/ _____/ _____ _____
2) _____/ _____/ _____ _____
3) _____/ _____/ _____ _____ _Tech

10) Cholesterol (mg/dl) TC ________
HDL _______
TRIG ______ _Tech

11) PWC_{170} Weight used to set initial load _____kg.

Workload	Minute 1	Minute 2	Minute 3	
______Watts	__________	__________	__________	
______Watts	__________	__________	__________	
______Watts	__________	__________	__________	HR>150?
______Watts	__________	__________	__________	

Tech

APPENDIX I: Physiological Date Sheet (Elementary and High School Version: Cohort 4&5)

1) Name: ____________________________
2) Date: __ __/__ __/__ __
3) Grade: ______
4) Sex (M or F): ______
5) Age (yrs): __ __
6) Height (nearest 0.1 mm) __ __ __.__
7) Weight (nearest 0.1 kg) __ __ __.__

Tech

8) Skinfolds and circumferences:

Right mid-arm circumference		(cm)	___ ___.___
Waist		(cm)	___ ___.___
Hip		(cm)	___ ___.___
(To nearest 0.5 mm)	Tricep		1)___ ___.___ 2)___ ___.___ 3)___ ___.___
	Scapula		1)___ ___.___ 2)___ ___.___ 3)___ ___.___

______ Tech

Medicines ____

Recent Illness ____

Asthma YES NO Last attack: ____

9) Blood Pressure Cuff Size __________ cm

			r. zero
(Right Arm)	1) ____/	_____	____
	2) ____/	_____	____
	3) ____/	_____	____

_____ Tech

10) PWC_{195} Weight used to set initial load ________kg.

Workload	Minute 1	Minute 2	Minute 2:30	Minute 3	
______ kp	__________	_____	__________	________	
______ kp	__________	_____	__________	________	
______ kp	__________	_____	__________	________	HR>150? if NO,
______ kp	__________	_____	__________	________	

______ Tech

APPENDIX J: Pubertal Developmental Scale for Girls

At your age, girls usually begin to experience many physical changes. Please indicate any changes you have experienced.

1. Have you noticed any skin changes like oily skin, pimples or acne?
____a - My skin has not yet started showing changes
____b - My skin has barely started showing changes
____c - My skin changes are definitely underway
____d - My skin changes are completed
2. Girls your age often experience a sudden increase in their height called a "growth spurt".
Would you say your growth spurt...
____a - Has not yet begun
____b - Has barely started
____c - Is definitely underway
____d - Seems completed
3. Have you noticed an increase in your weight over the last few months?
____a - I have not noticed an increase in weight
____b - I have barely noticed an increase in weight
____c - An increase in my body weight is definitely underway
____d - My body weight seems to have increased as much as it's going to

4. And how about the growth of underarm and pubic hair? Would you say it has...
____a - not started growing yet
____b - has barely started
____c - is definitely underway
____d - seems completed
5. Have your breasts begun to develop?
____a - Not yet started breast development
____b - Have barely started breast development
____c - Breast development is definitely underway
____d - Breast development is completed
6. How old were you when you had your first menstrual period?
____a - _______ years old
____b - I have not started getting my monthly period yet.

YOU ARE FINISHED,
1- Fold this questionnaire and staple it closed.
2- Place it in the collection box provided.

APPENDIX K: Pubertal Developmental Scale for Boys

At your age, boys usually begin to experience many physical changes. Please indicate any changes you have experienced.

1. Have you noticed any skin changes like oily skin, pimples or acne?
_____a - My skin has not yet started showing changes
_____b - My skin has barely started showing changes
_____c - My skin changes are definitely underway
_____d - My skin changes are completed
2. Boys your age often experience a sudden increase in their height called a "growth spurt".
Would you say your growth spurt...
_____a - Has not yet begun
_____b - Has barely started
_____c - Is definitely underway
_____d - Seems completed
3. Have you noticed a deepening of your voice?
_____a - My voice has not yet started changing
_____b - My voice has barely started changing
_____c - My voice change is definitely underway
_____d - My voice change has been completed
4. And how about the growth of underarm and pubic hair? Would you say it has...
_____a - not started growing yet
_____b - has barely started
_____c - is definitely underway
_____d - seems completed
5. Have you noticed an increase in your weight over the last few months?
_____a - I have not noticed an increase in weight
_____b - I have barely noticed an increase in weight
_____c - An increase in my body weight is definitely underway
_____d - My body weight seems to have increased as much as it's going to
6. Have you begun to grow hair on your face?
_____a - Not yet started growing hair
_____b - Have barely started growing hair
_____c - Facial hair growth is definitely underway
_____d - Facial hair growth is complete

YOU ARE FINISHED,
1- Fold this questionnaire and staple it closed.
2- Place it in the collection box provided.

APPENDIX L: Parental SES, Activity, and Obesity Questions

9. What is your total family income?
(Check the one response that best answers the question.)
_____a. less than $5000
_____b. $5,000-$9,999
_____c. $10,000-$19,999
_____d. $20,000-$29,999
_____e. $30,000-$39,999
_____f. $40,000-$49,999
_____g. $50,000-$74,999
_____h. $75,000-$100,000
_____i. above $100,000

The next questions are about ***you*** *and your health habits*

10. What is the highest grade you finished in school?
(Check the one response that best answers the question.)

_____a. Sixth grade or less
_____b. Junior high (7th g-9th grade)
_____c. Some high school (10th or 11th grade)
_____d. High school graduate
_____e. Some college or specialized training
_____f. College or university graduate
_____g. Graduate professional training (graduate degree)

12. How tall are you? _____feet and _____inches.
13. How much do you weigh? _____lbs.

17. In the last 6 months, about how often did you participate in one or more physical activities that lasted 20-30 minutes? *(Check the one response that best answers the question.)*

_____a. Not at all
_____b. Less than once a month
_____c. About once a month
_____d. 2-3 times a month
_____e. 1-2 times a week
_____f. 3 or more times a week

APPENDIX M: Figures (4.2.5 to 4.2.23) and Tables from Research Question 2

Figure 4.2.5

LPA and Age by Puberty

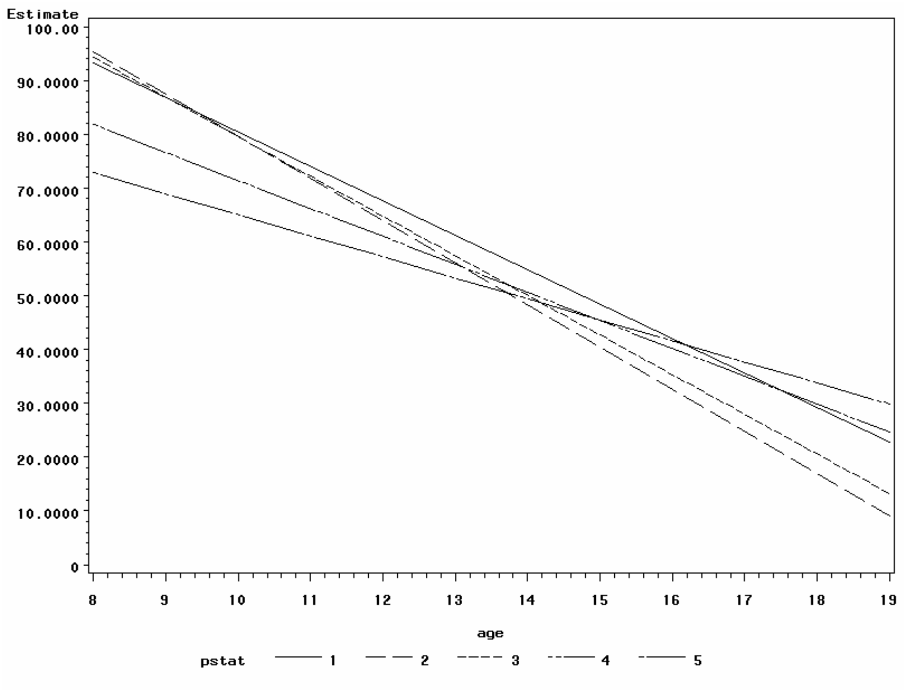


Figure 4.2.6

MPA and Age by Puberty

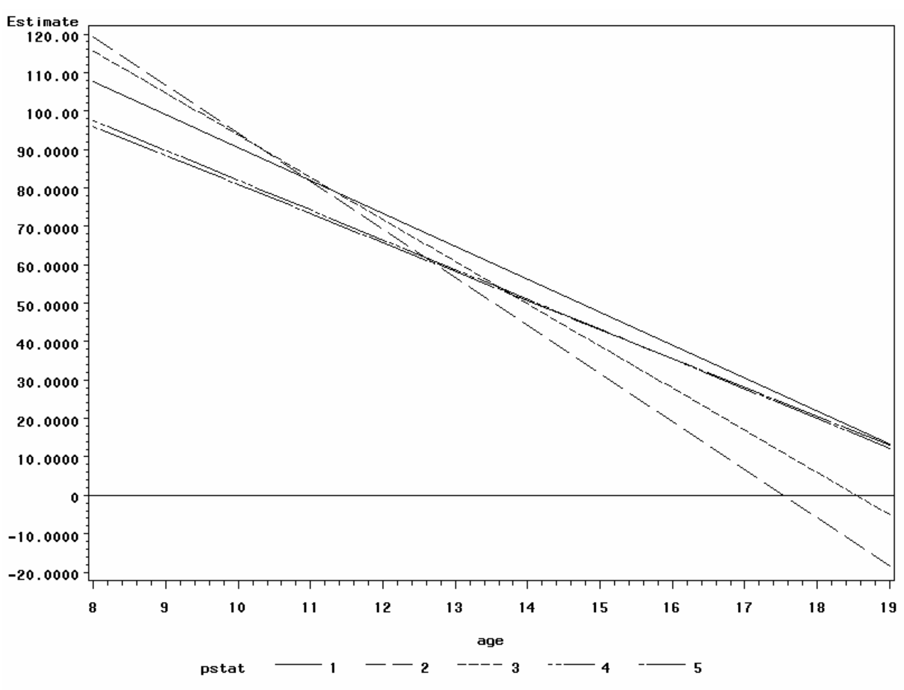


Figure 4.2.7

VPA and Age by Puberty

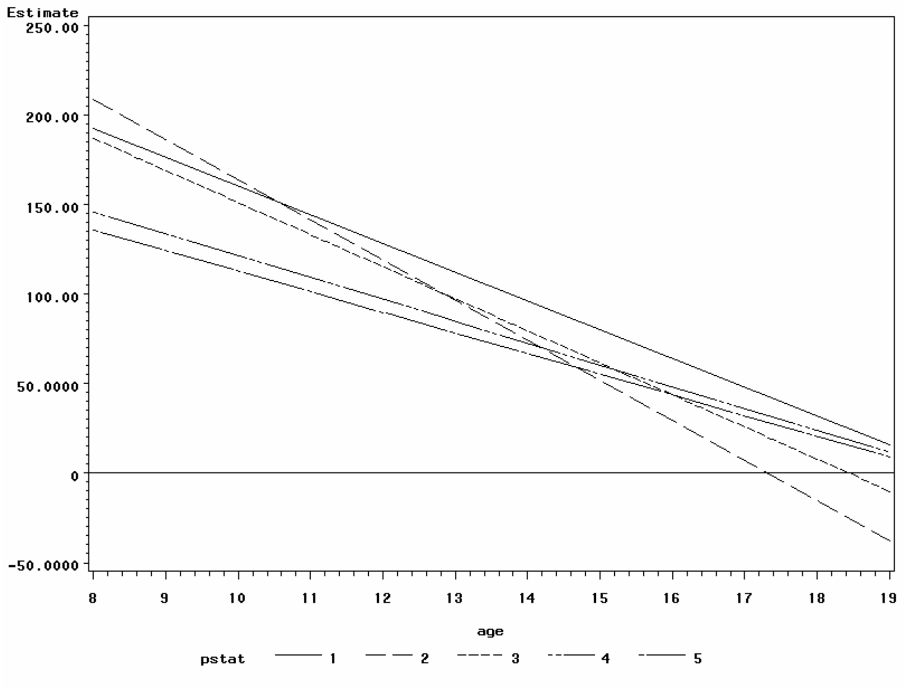


Figure 4.2.8

LPA and Age by Sex

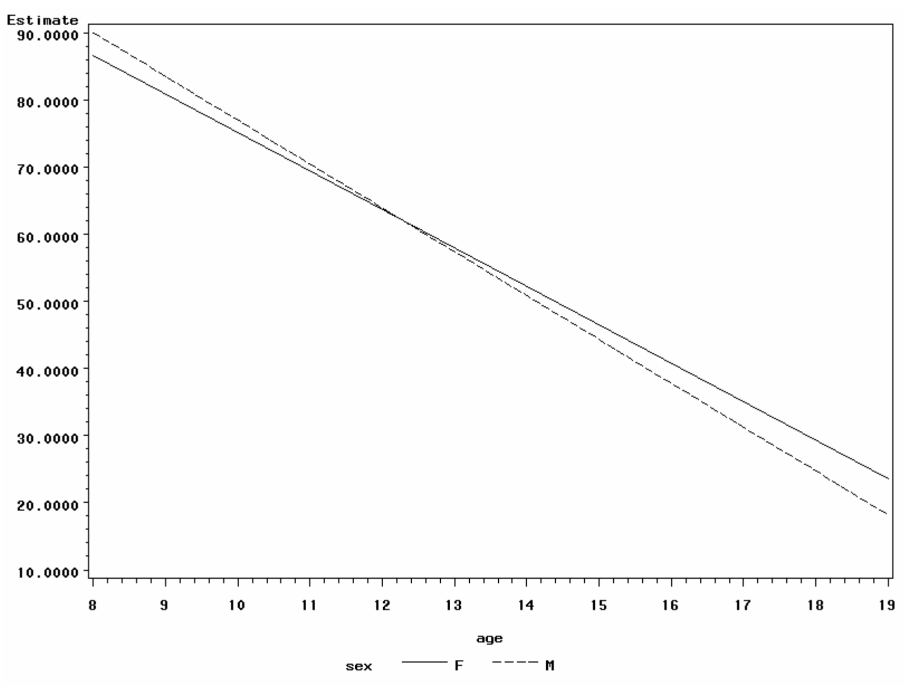


Figure 4.2.9

MPA and Age by Race

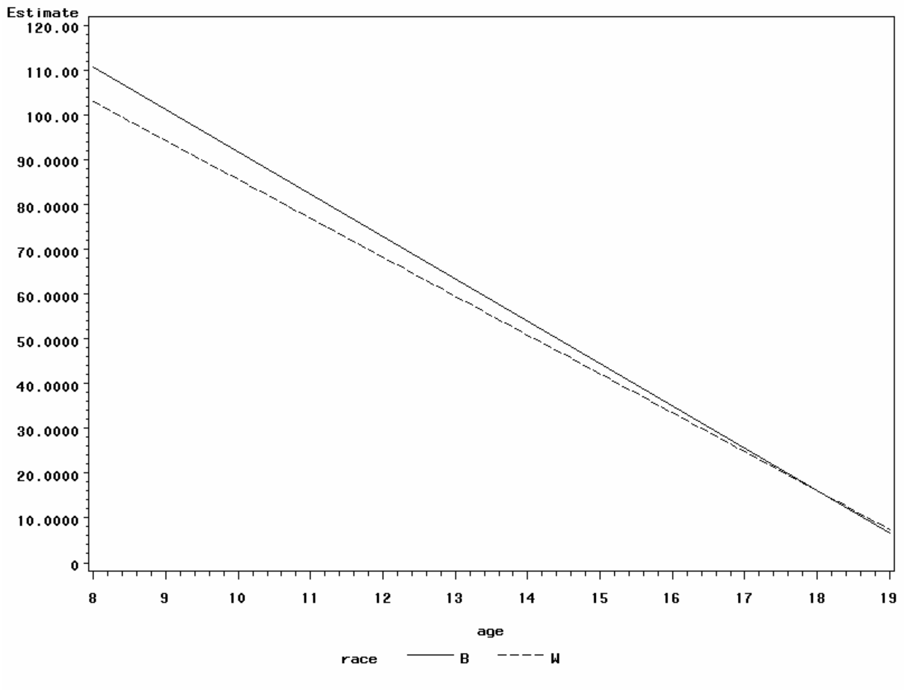


Figure 4.2.10

VPA and Age by Race

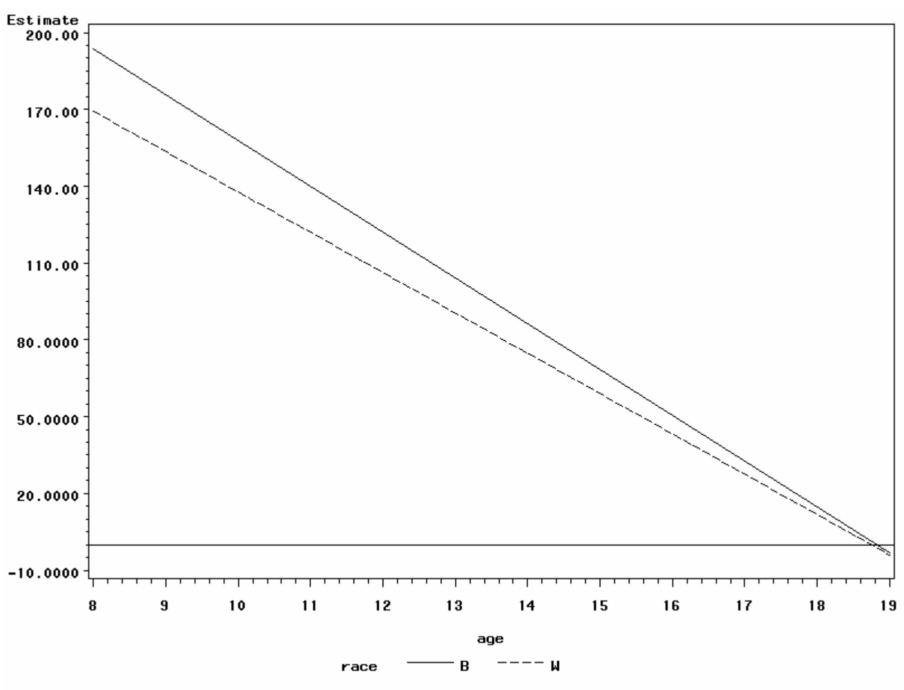


Figure 4.2.11

Total PA and Age by Parental Education

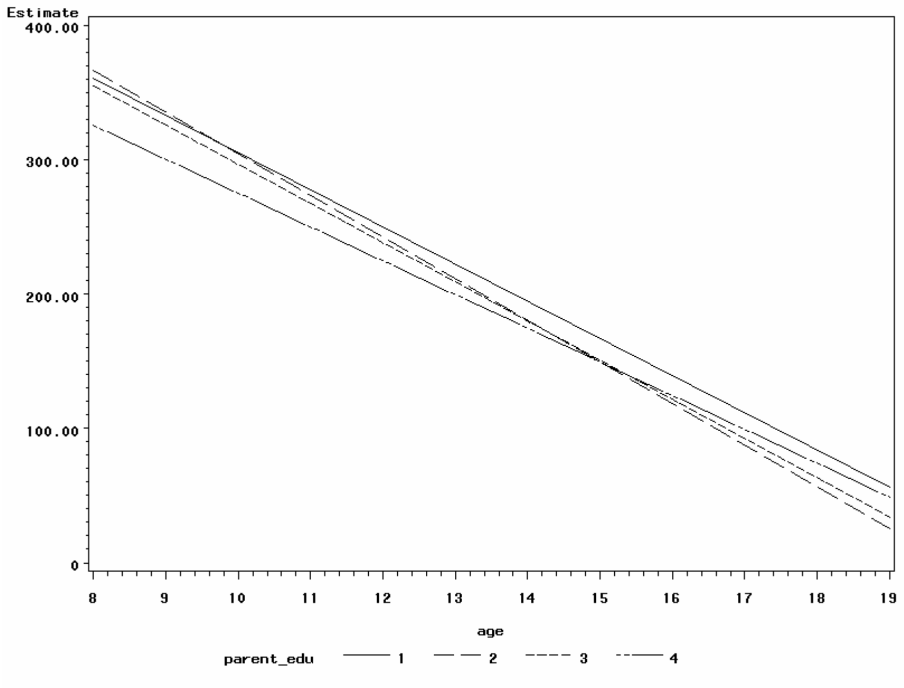


Figure 4.2.12

MPA and Age by Parental Education

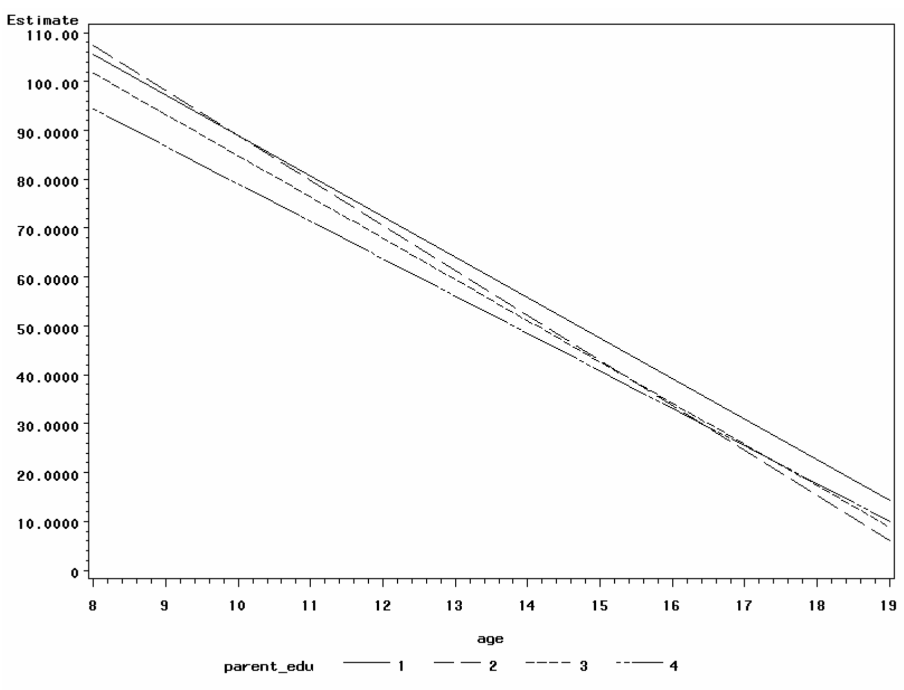


Figure 4.2.13

VPA and Age by Parental Education

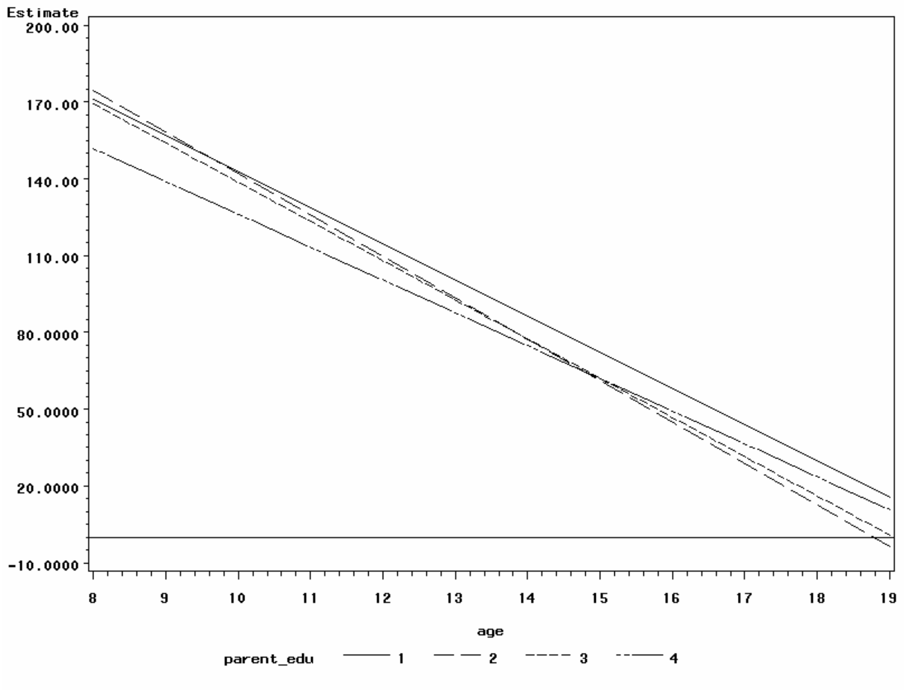


Figure 4.2.14

VPA and Age by Parental Activity

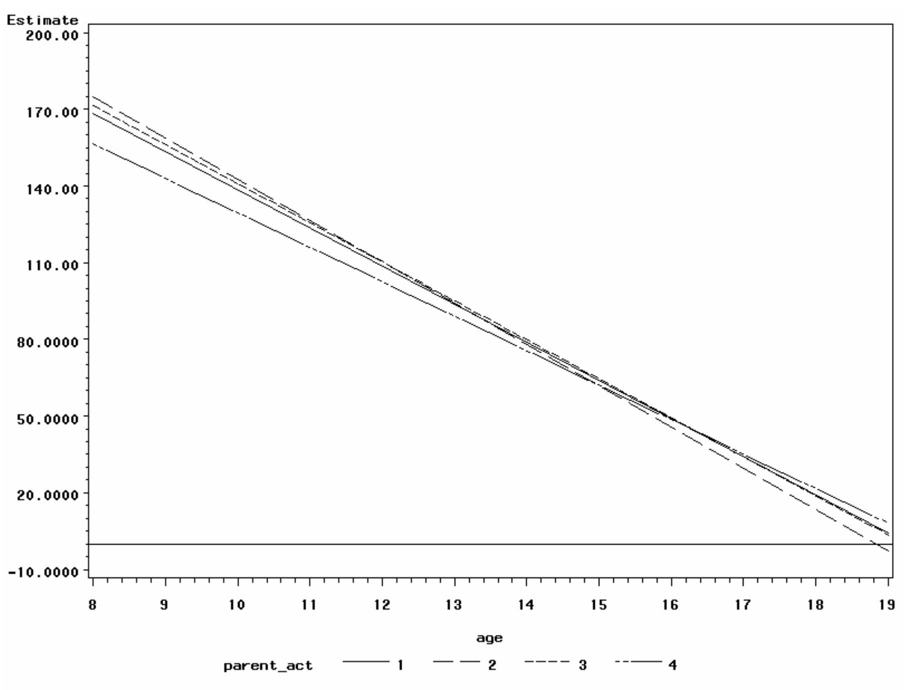


Figure 4.2.15

LPA and Age by Parental BMI Risk

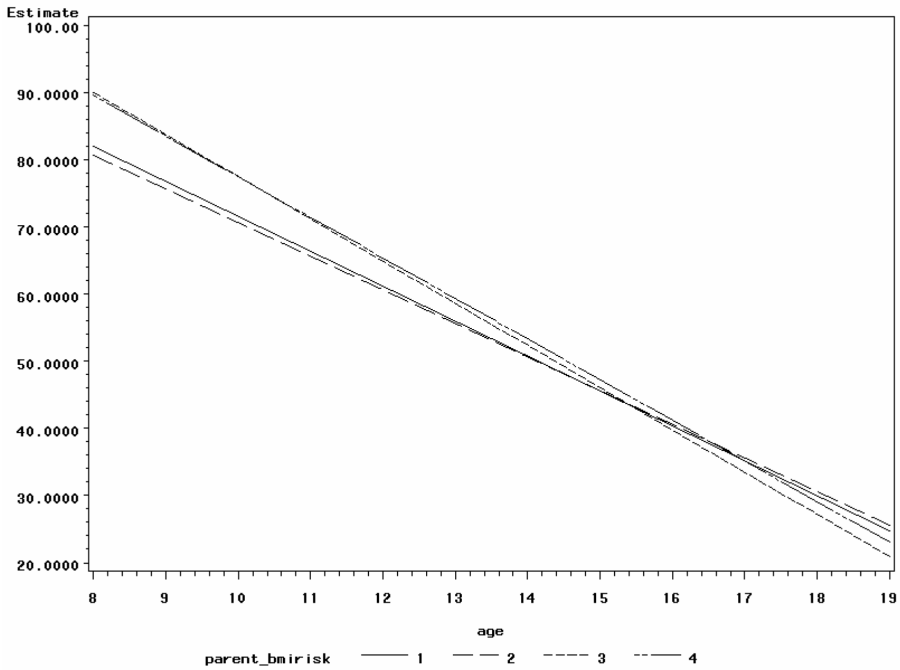


Figure 4.2.16

MPA and Age by Parental BMI Risk

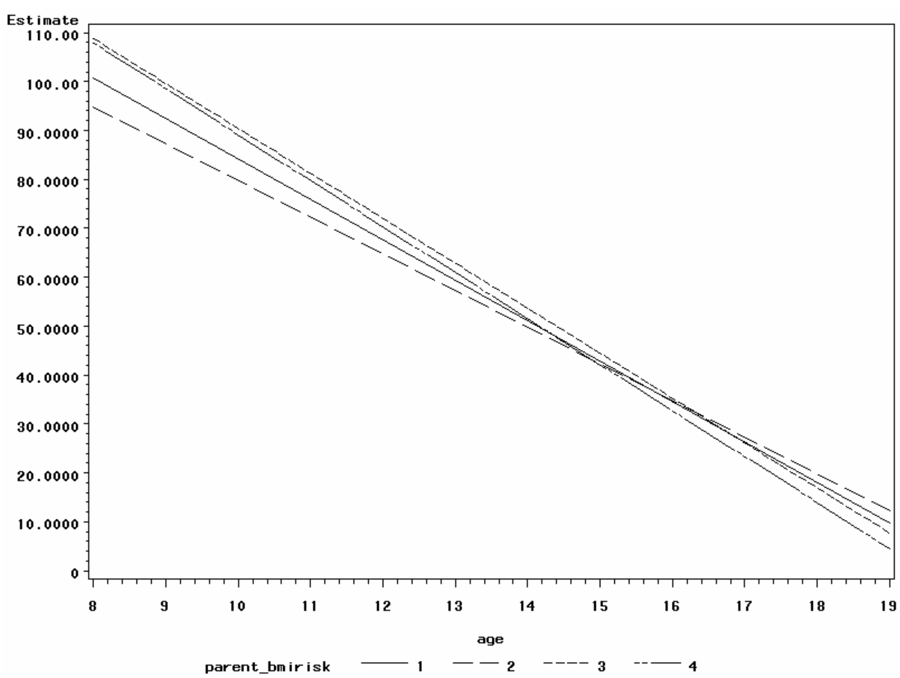


Figure 4.2.17

VPA and Age by Parental BMI Risk

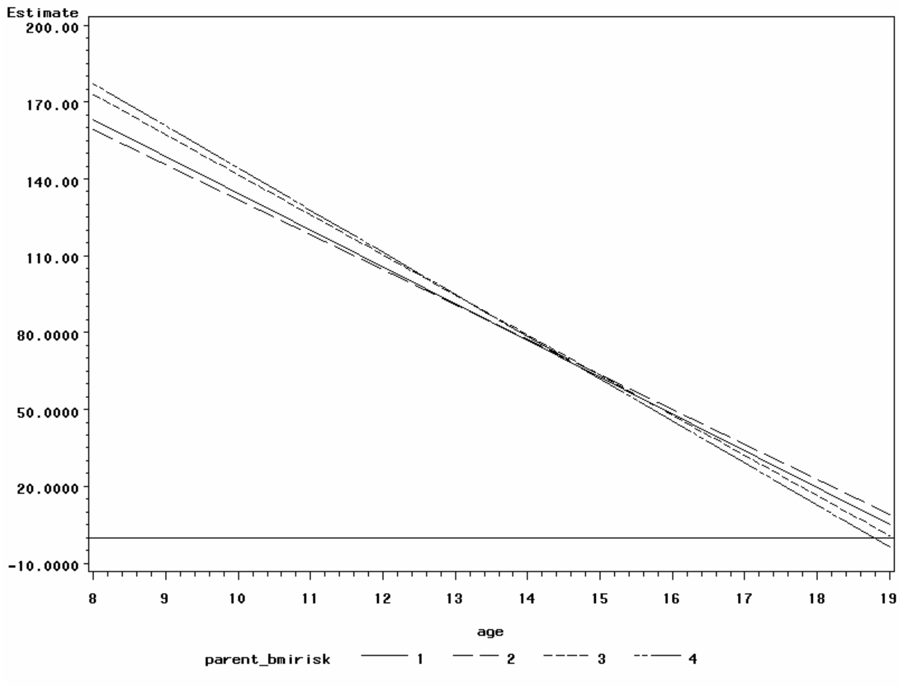


Figure 4.2.18

Total PA and Age by Sex (from Model with Child Variables)

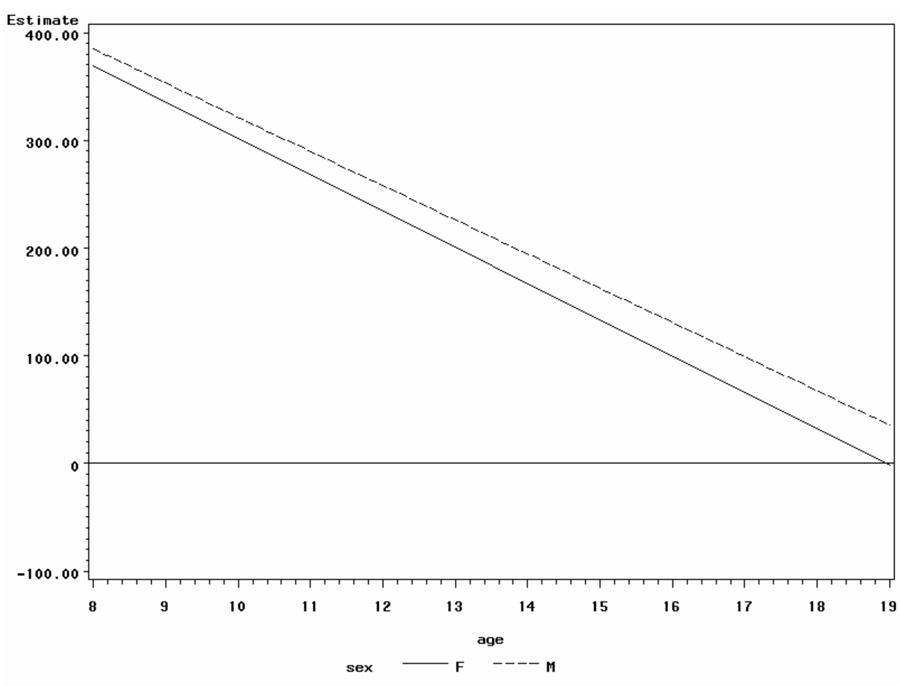


Figure 4.2.19

MPA and Age by Sex (from Model with Child Variables)

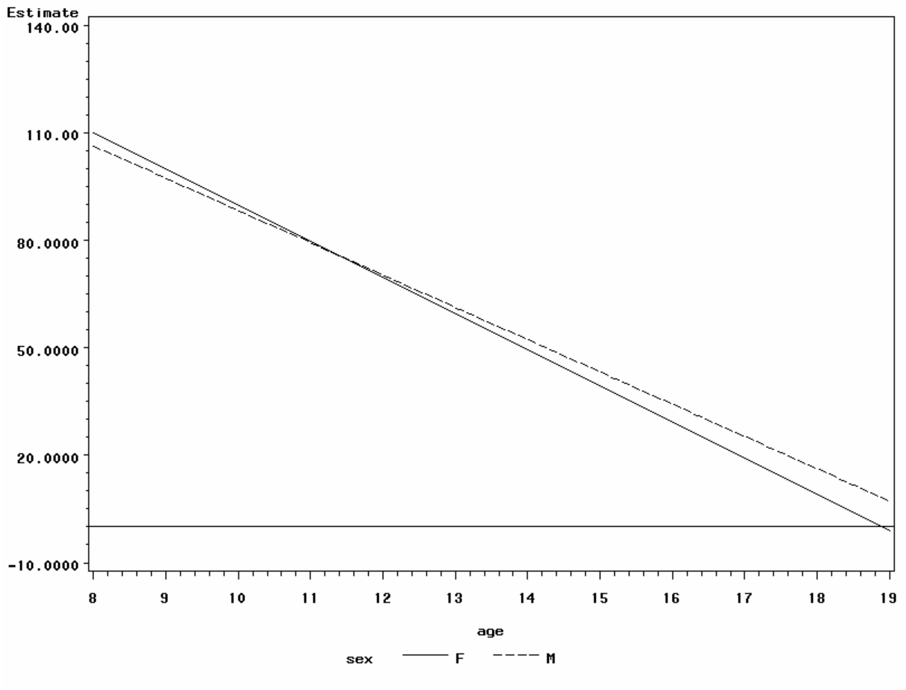


Figure 4.2.20

VPA and Age by Sex (from Model with Child Variables)

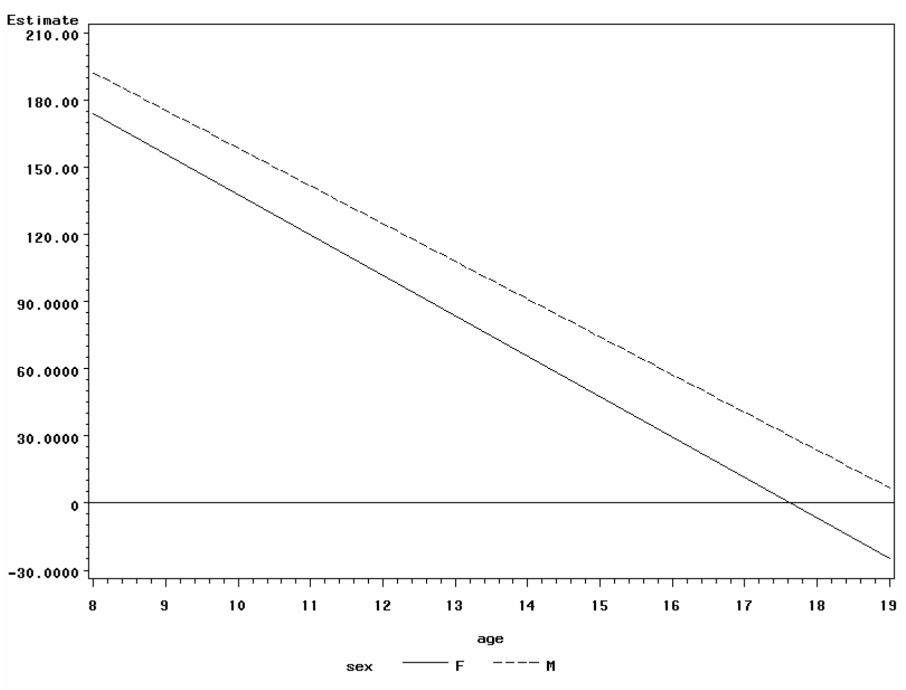


Figure 4.2.21

MPA and Age by Sex (from Final Model)

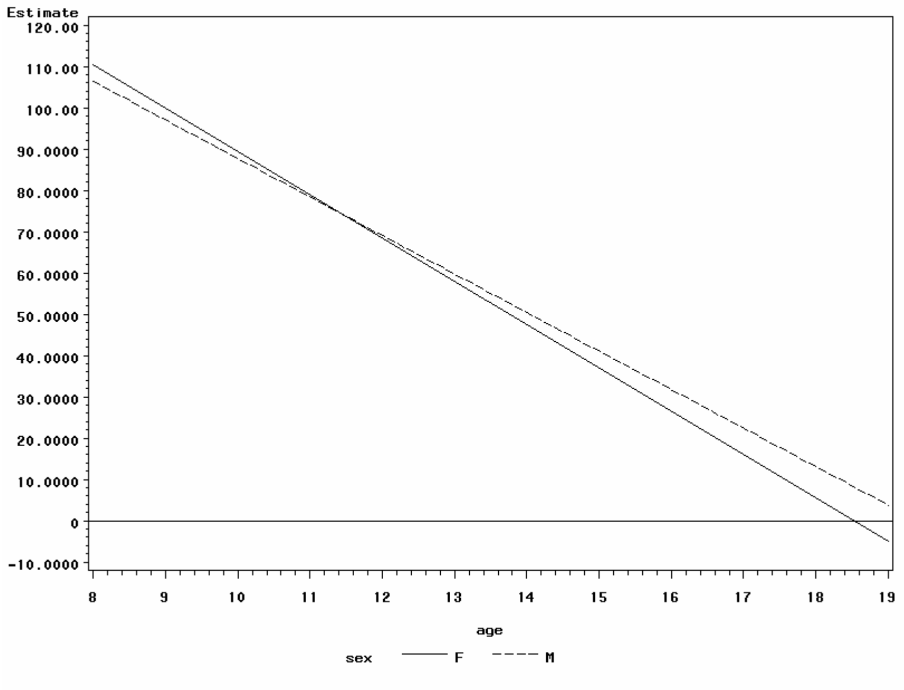


Figure 4.2.22

LPA and Age by Family Income (from Final Model)

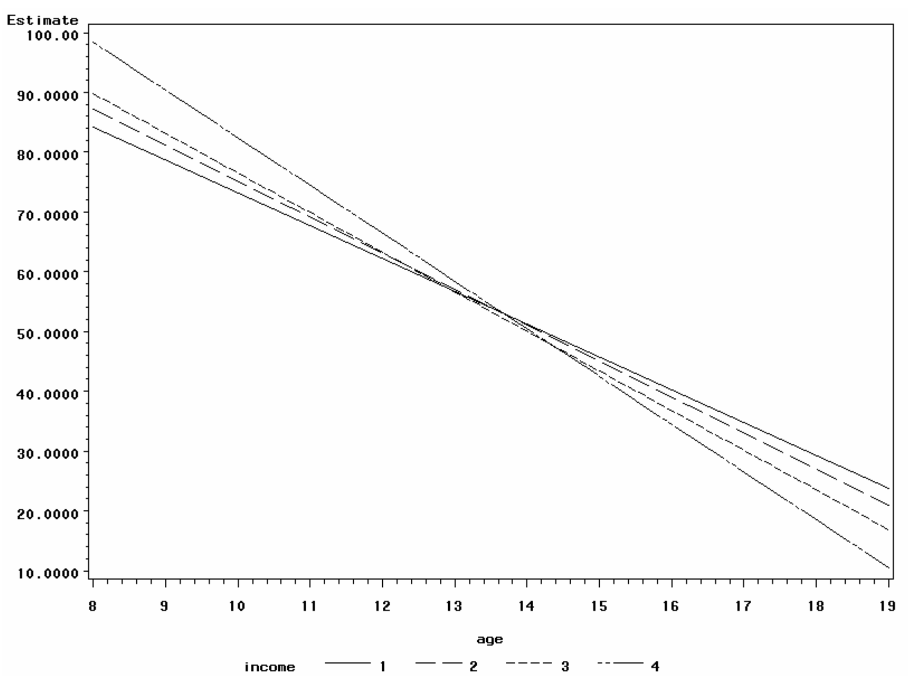


Figure 4.2.23

VPA and Age by Family Income (from Final Model)

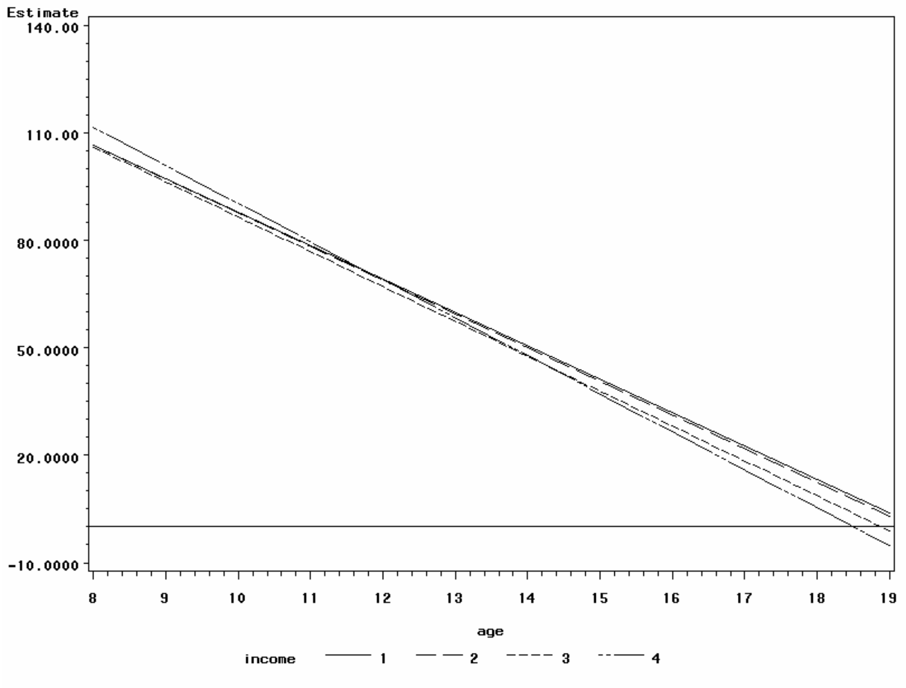


Table 4.3.1

Predictors of Physical Activity across Age (Child Variables) (n=8642)

Total PA score				LPA score			MPA score			VPA score		
		Estimate	SE		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		466.6	34.1	Intercept	99.4	8.2	Intercept	142.8	12.4	Intercept	232.0	21.1
Age ***		-20.6	2.1	Age ***	-3.8	0.5	Age ***	-6.5	0.8	Age ***	-10.7	1.3
Pstat ***	1	164.4	45.2	Pstat ***	45.6	10.6	Pstat ***	25.3	16.3	Pstat ***	90.7	27.9
	2	289.4	39.3		57.0	9.3		68.3	14.3		160.2	24.3
	3	219.6	34.7		51.1	8.4		52.4	12.7		113.7	21.4
	4	52.6	33.2		19.6	8.0		6.5	12.2		24.5	20.5
	5	0	.		0	.		0	.		0	.
Sex	F	1.2	12.8	Sex	-3.6	3.0	Sex **	12.5	4.6	Sex	-8.4	7.9
	M	0	.		0	.		0	.		0	.
Race ***	B	53.5	12.2	Race **	8.4	2.9	Race *	10.0	4.4	Race ***	34.0	7.6
	W	0	.		0	.		0	.		0	.
Age x pstat ***	1	-9.8	3.63	Age x pstat ***	-2.8	0.8	Age x pstat ***	-1.5	1.3	Age x pstat ***	-5.4	2.2
	2	-21.8	2.8		-4.1	0.7		-5.4	1.0		-12.1	1.7
	3	-15.7	2.2		-3.5	0.5		-3.9	0.8		-8.2	1.4
	4	-3.5	2.0		-1.3	0.5		-0.5	0.8		-1.7	1.3
	5	0	.		0	.		0	.		0	.
Age x sex *	F	-2.0	0.9	Age x sex	0.3	0.2	Age x sex **	-1.1	0.3	Age x sex *	-1.2	0.6
	M	0	.		0	.		0	.		0	.
Age x race *	B	-2.0	0.9	Age x race	-0.1	0.2	Age x race	-0.4	0.3	Age x race *	-1.4	0.5
	W	0	.		0	.		0	.		0	.

Note. *p<0.05, **p<0.01, ***p<0.0001 (from type 3 test of fixed effect)

Table 4.3.2

Predictors of Physical Activity across Age (Type 3 Test from Full Model)

	Outcome: Total PA			LPA			MPA			VPA		
Effect	DF	F	p	DF	F	P	DF	F	p	DF	F	p
Age	1	710.72	<.0001	1	447.48	<.0001	1	463.30	<.0001	1	520.94	<.0001
Puberty	4	23.61	<.0001	4	17.78	<.0001	4	12.19	<.0001	4	18.51	<.0001
Sex	1	0.09	0.7681	1	0.02	0.8929	1	3.36	0.0671	1	0.51	0.4741
Race	1	18.54	<.0001	1	13.82	0.0002	1	9.96	0.0016	1	14.78	0.0001
Family income	3	4.34	0.0047	3	5.52	0.0009	3	0.65	0.5845	3	4.75	0.0026
Parental education	3	5.10	0.0016	3	4.30	0.0050	3	1.82	0.1413	3	4.55	0.0035
Parental activity	3	1.60	0.1883	3	0.93	0.4277	3	0.12	0.9478	3	2.78	0.0395
Parental BMI risk	3	2.86	0.0355	3	3.81	0.0098	3	3.86	0.0091	3	0.79	0.5018
Age x puberty	4	23.79	<.0001	4	17.17	<.0001	4	13.00	<.0001	4	18.24	<.0001
Age x sex	1	3.39	0.0656	1	0.29	0.5894	1	5.32	0.0212	1	2.72	0.0992
Age x race	1	9.87	0.0017	1	4.87	0.0274	1	7.09	0.0078	1	7.66	0.0057
Age x family income	3	4.33	0.0047	3	6.11	0.0004	3	0.89	0.4436	3	4.06	0.0069
Age x p_education	3	5.22	0.0014	3	4.78	0.0025	3	1.53	0.2038	3	4.68	0.0029
Age x p_activity	3	1.41	0.2385	3	0.77	0.5091	3	0.16	0.9249	3	2.36	0.0697
Age x p_BMI risk	3	2.55	0.0541	3	2.91	0.0332	3	3.11	0.0255	3	0.83	0.4785

Note. Shaded cell: p<0.05

APPENDIX N: Figures (4.3.3 to 4.3.6) and Tables from Research Question 3

Figure 4.3.3

Hours of TV Viewing and Age by Puberty

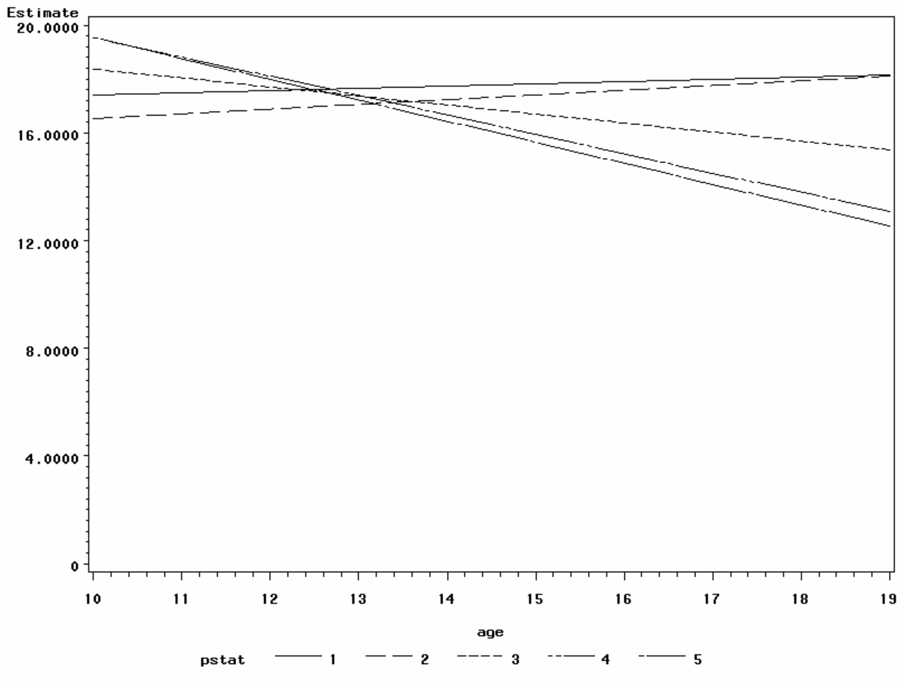


Figure 4.3.4

Hours of Video Games and Age by Family Income

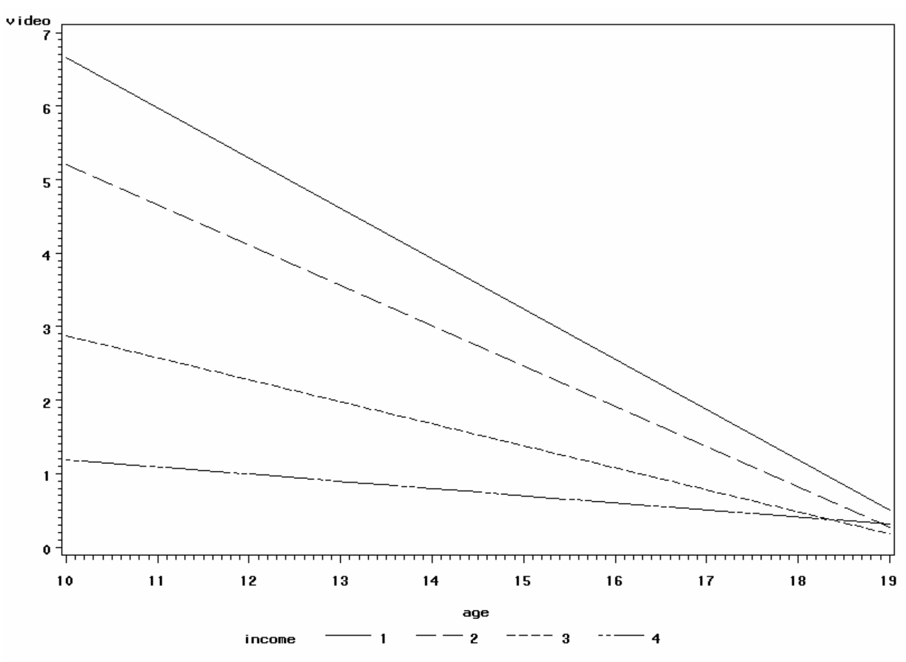


Figure 4.3.5

Hours of Video Games and Age by Parental Activity

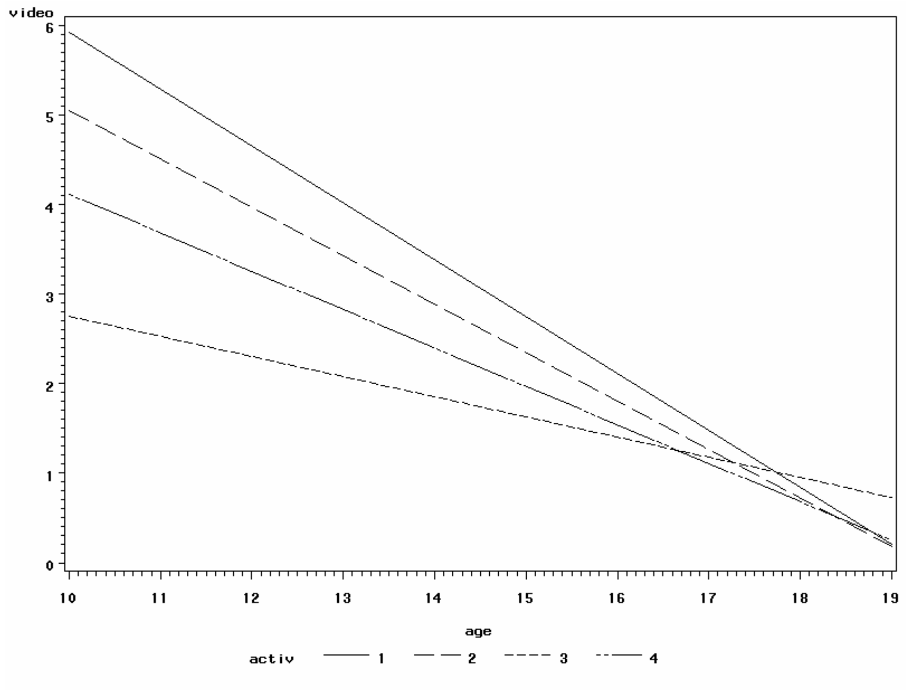


Figure 4.3.6

Hours of Video Games and Age by Puberty (from Models with Child variables)

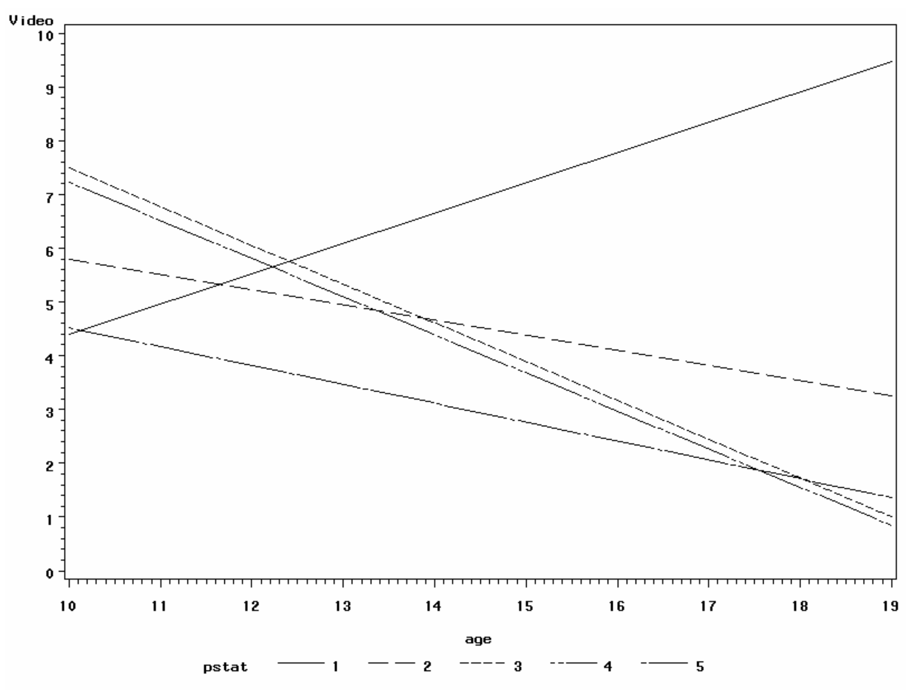


Table 4.4.1

Predictors of Sedentary Behaviors across Age (Child Variables)

Outcome: TV (N=5443)				Square rooted Video (N=5441)			Computer (N=1738)		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		29.5	3.1	Intercept	2.6	0.7	Intercept	16.4	8.5
Age		-1.0	0.2	Age	-0.1	0.04	Age	-0.5	0.5
Pstat	1	-12.1	12.0	Pstat *	-2.2	2.7	Pstat	-4.3	6.4
	2	-9.6	5.2		-0.1	1.1		1.3	55.1
	3	-5.2	3.2		1.5	0.7		-2.2	11.0
	4	-0.9	2.8		1.5	0.6		-0.9	7.2
	5	0	.		0	.		0	.
Sex	F	-2.9	1.8	Sex	-0.7	0.4	Sex	-7.8	6.6
	M	0	.		0	.		0	.
Race	B	0.5	1.8	Race ***	1.9	0.4	Race	3.5	5.9
	W	0	.		0	.		0	.
Age x pstat	1	0.9	1.0	Age x pstat *	0.2	0.2	Age x pstat	0	.
	2	0.7	0.4		0.04	0.1		-0.5	3.5
	3	0.4	0.2		-0.1	0.04		0.2	0.7
	4	0.1	0.2		-0.1	0.04		0.1	0.4
	5	0	.		0	.		0	.
Age x sex	F	0.1	0.1	Age x sex	-0.03	0.03	Age x sex	0.5	0.4
	M	0	.		0	.		0	.
Age x race **	B	0.3	0.1	Age x race *	-0.1	0.03	Age x race	-0.2	0.4
	W	0	.		0	.		0	.

Note. *p<0.05, **p<0.01, ***p<0.0001 (from type 3 test of Fixed effect)

Table 4.4.2

Predictors of Sedentary Behaviors across Age (Type 3 Test from Full Model)

Effect	Outcome: TV			Square Rooted Video			Computer		
	DF	F	p	DF	F	p	DF	F	p
Age	1	0.09	0.7649	1	2.17	0.1413	1	0.72	0.3961
Puberty	4	1.85	0.1174	4	1.01	0.3992	3	1.24	0.2988
Sex	1	1.83	0.1765	1	5.46	0.0195	1	0.43	0.5103
Race	1	1.13	0.2885	1	17.55	<.0001	1	0.09	0.7616
Family income	3	0.35	0.7858	3	1.67	0.1717	3	1.15	0.3277
Parental education	3	0.54	0.6549	3	0.95	0.4166	3	0.22	0.8811
Parental activity	3	0.34	0.7964	3	2.44	0.0630	3	1.41	0.2403
Parental BMI risk	3	1.84	0.1387	3	3.23	0.0216	3	1.09	0.3536
Age x puberty	4	1.90	0.1084	4	1.01	0.4024	3	1.38	0.2475
Age x sex	1	0.57	0.4520	1	0.17	0.6803	1	0.40	0.5269
Age x race	1	0.72	0.3956	1	7.97	0.0048	1	0.19	0.6611
Age x family income	3	0.08	0.9727	3	1.05	0.3680	3	1.39	0.2462
Age x p_education	3	0.18	0.9104	3	0.54	0.6578	3	0.24	0.8658
Age x p_activity	3	0.40	0.7508	3	2.44	0.0627	3	1.48	0.2198
Age x p_BMI risk	3	1.52	0.2074	3	3.20	0.0224	3	1.22	0.3035

Note. Shaded cell: p<0.05

APPENDIX O: Figures (4.4.2 to 4.4.4) and Tables from Research Question 4

Figure 4.4.2

VPA and age by TV Viewing

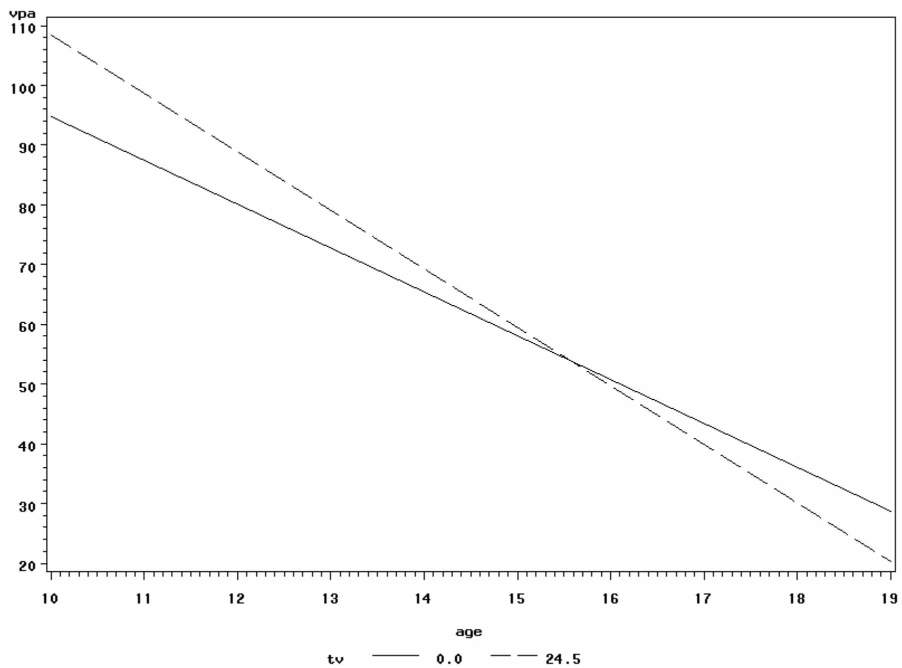


Figure 4.4.3

MPA and Age by Computer Use

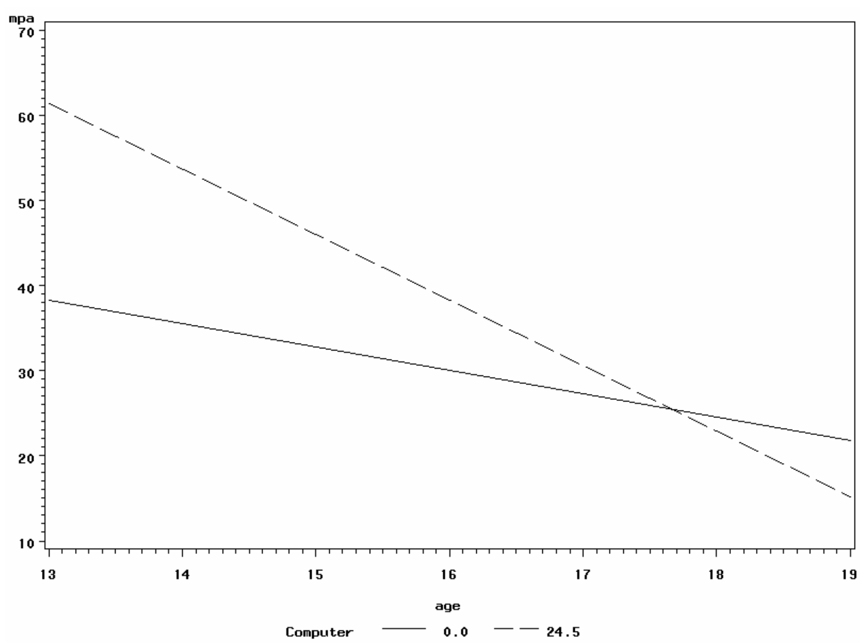


Figure 4.4.4

VPA and age by Computer Use

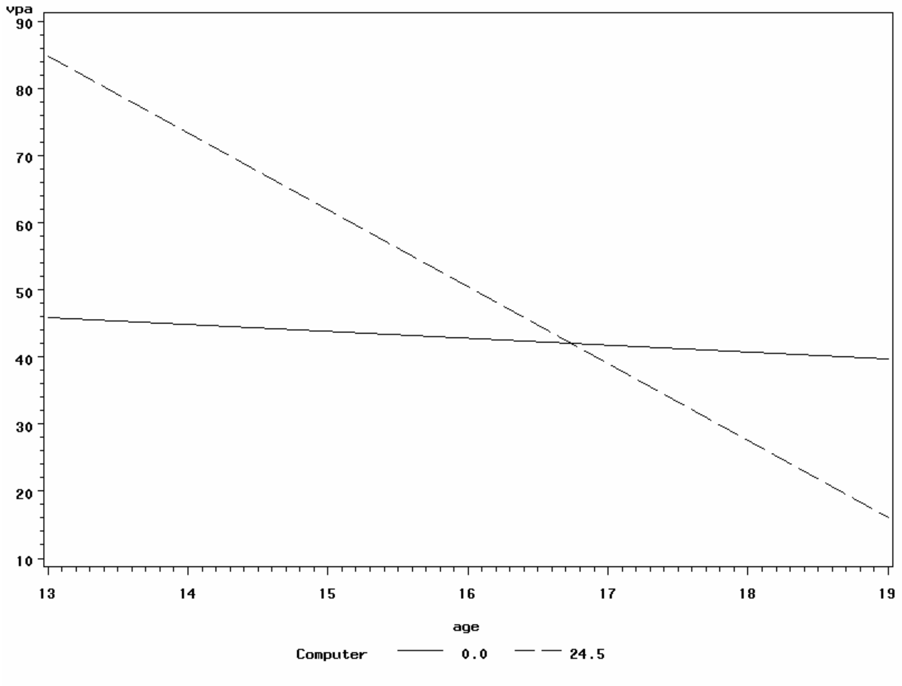


Table 4.5.1

Sedentary Behaviors and MPA across Age When Controlling for Child Variables

TV and MPA N=5339				Video and MPA N=5338			Computer and MPA N=1673		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		127.71	15.08	Intercept	120.19	13.97	Intercept	7.40	32.57
Age **		-5.64	0.93	Age ***	-5.34	0.86	Age	1.12	1.89
TV		-0.31	0.48	Video	0.17	0.46	Computer **	3.73	1.31
Pstat	1	-130.89	57.14	Pstat	-127.38	57.05	Pstat	43.89	26.85
	2	-23.99	24.88		-23.65	24.74		88.70	287.31
	3	7.94	14.09		4.90	14.03		76.99	39.77
	4	0.76	12.19		0.07	12.13		16.30	25.27
	5	0	.		0	.		0	.
Sex	F	14.26	7.68	Sex *	16.10	7.91	Sex **	64.90	22.76
	M	0	.		0	.		0	.
Race	B	15.86	8.42	Race	11.38	8.26	Race	16.75	20.37
	W	0	.		0	.		0	.
TV x age		0.02	0.03	Video x Age	0.01	0.03	Computer x age **	-0.21	0.08
Age x pstat	1	9.85	4.55	Age x pstat	9.51	4.54	Age x pstat	0	.
	2	1.58	1.83		1.51	1.81		-4.39	18.25
	3	-0.70	0.90		-0.51	0.90		-4.82	2.40
	4	-0.07	0.75		-0.04	0.75		-0.92	1.47
	5	0	.		0	.		0	.
Age x sex *	F	-1.09	0.50	Age x sex *	-1.10	0.52	Age x sex **	-3.98	1.34
	M	0	.		0	.		0	.
Age x race	B	-0.7	0.55	Age x race	-0.52	0.54	Age x race	-0.73	1.20
	W	0	.		0	.		0	.

Note. *p<0.05, **p<0.01, ***p<0.0001 (from type 3 test of Fixed effect)

Table 4.5.2

Sedentary Behaviors and VPA across Age When Controlling for Child Variables

TV and VPA N=5339				Video and VPA N=5338			Computer and VPA N=1673		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		191.32	24.16	Intercept	198.40	22.33	Intercept	20.78	50.25
Age ***		-8.01	1.50	Age ***	-8.93	1.38	Age	1.90	2.91
TV		1.06	0.78	Video	0.43	0.73	Computer **	6.87	1.99
Pstat	1	-30.22	92.22	Pstat	-15.74	91.81	Pstat	60.94	39.56
	2	-17.07	39.94		-10.61	39.60		-273.78	437.24
	3	-4.05	22.60		-6.85	22.43		62.24	61.79
	4	-17.20	19.53		-20.06	19.39		-7.78	38.85
	5	0	.		0	.		0	.
Sex	F	-14.25	12.54	Sex	-8.80	12.82	Sex	35.83	35.03
	M	0	.		0	.		0	.
Race **	B	45.57	13.62	Race **	44.64	13.31	Race	24.39	31.52
	W	0	.		0	.		0	.
TV x age		-0.09	0.05	Video x Age	0.02	0.05	Computer x age **	-0.41	0.12
Age x pstat	1	1.65	7.35	Age x pstat	0.39	7.32	Age x pstat	0	.
	2	0.94	2.93		0.38	2.90		18.61	27.84
	3	0.12	1.45		0.24	1.44		-3.55	3.73
	4	1.03	1.20		1.16	1.19		0.47	2.26
	5	0	.		0	.		0	.
Age x sex	F	-0.62	0.82	Age x sex	-0.75	0.84	Age x sex	-3.68	2.06
	M	0	.		0	.		0	.
Age x race *	B	-1.86	0.88	Age x race *	-2.08	0.86	Age x race	-1.01	1.85
	W	0	.		0	.		0	.

Note. *p<0.05, **p<0.01, ***p<0.0001 (from type 3 test of Fixed effect)

Table 4.5.3

Sedentary Behaviors and Total PA across Age When Controlling for Child Variables

TV and Total PA N=5339				Video and Total PA N=5338			Computer and Total PA N=1673		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		366.84	38.73	Intercept	376.86	35.61	Intercept	100.93	81.21
Age ***		-14.61	2.39	Age ***	-15.82	2.19	Age	0.69	4.70
TV		1.81	1.24	Video	2.28	1.18	Computer **	10.71	3.26
Pstat	1	-99.46	149.08	Pstat	-80.94	147.63	Pstat	126.64	72.12
	2	6.71	64.42		8.93	63.50		-233.14	758.50
	3	39.16	36.15		24.17	35.69		165.77	100.64
	4	3.50	31.15		-5.13	30.75		-14.63	62.77
	5	0	.		0	.		0	.
Sex	F	6.51	20.13	Sex	21.85	20.48	Sex *	117.44	56.34
	M	0	.		0	.		0	.
Race **	B	65.24	21.95	Race *	53.60	21.33	Race	15.56	50.46
	W	0	.		0	.		0	.
TV x age		-0.12	0.08	Video x Age	-0.04	0.08	Computer x age **	-0.61	0.19
Age x pstat	1	7.03	11.88	Age x pstat	5.20	11.76	Age x pstat	0	.
	2	-0.69	4.73		-1.11	4.66		18.21	48.25
	3	-2.83	2.31		-1.95	2.28		-9.85	6.06
	4	-0.27	1.91		0.20	1.89		0.84	3.65
	5	0	.		0	.		0	.
Age x sex	F	-1.88	1.31	Age x sex	-2.42	1.33	Age x sex *	-8.48	3.30
	M	0	.		0	.		0	.
Age x race	B	-2.46	1.42	Age x race	-2.11	1.37	Age x race	-0.04	2.96
	W	0	.		0	.		0	.

Note. *p<0.05, **p<0.01, ***p<0.0001 (from type 3 test of Fixed effect)

Table 4.5.4

Relationships between Sedentary Behaviors and Moderate Physical Activity (Type 3 Test from Full Model)

Effect	TV and MPA N=4257			Video and MPA N=4258			Computer and MPA N=995		
	DF	F	p	DF	F	P	DF	F	p
Age	1	11.44	0.0007	1	11.96	0.0006	1	2.28	0.1318
Sedentary behaviors	1	0.20	0.6553	1	0.72	0.3963	1	7.25	0.0073
Puberty	4	1.21	0.3070	4	1.10	0.3578	3	1.18	0.3188
Sex	1	1.20	0.2739	1	2.25	0.1338	1	1.81	0.1794
Race	1	1.74	0.1871	1	0.51	0.4757	1	3.35	0.0678
Family income	3	0.84	0.4696	3	0.74	0.5286	3	2.29	0.0778
Parental education	3	0.49	0.6882	3	0.29	0.8349	3	0.26	0.8551
Parental activity	3	0.82	0.4833	3	0.69	0.5611	3	0.90	0.4432
Parental BMI risk	3	2.48	0.0597	3	2.02	0.1086	3	1.49	0.2167
Age x sedentary	1	0.02	0.8752	1	0.08	0.7799	1	6.38	0.0118
Age x puberty	4	1.13	0.3393	4	0.99	0.4094	3	1.24	0.2951
Age x sex	1	2.02	0.1556	1	2.75	0.0971	1	2.24	0.1352
Age x race	1	0.87	0.3508	1	0.24	0.6261	1	2.98	0.0850
Age x family income	3	0.55	0.6476	3	0.50	0.6835	3	2.20	0.0868
Age x p_education	3	0.67	0.5704	3	0.43	0.7314	3	0.25	0.8603
Age x p_activity	3	0.83	0.4780	3	0.62	0.6014	3	0.71	0.5440
Age x p_BMI risk	3	2.06	0.1038	3	1.69	0.1662	3	1.36	0.2531

Note. Shaded cell: $p<0.05$

Table 4.5.5

Relationships between Sedentary Behaviors and Vigorous Physical Activity (Type 3 Test from Full Model)

Effect	TV and VPA N=4257			Video and VPA N=4258			Computer and VPA N=995		
	DF	F	p	DF	F	P	DF	F	p
Age	1	23.37	<.0001	1	34.17	<.0001	1	1.01	0.3148
Sedentary behaviors	1	0.61	0.4331	1	0.00	0.9617	1	9.48	0.0022
Puberty	4	0.74	0.5644	4	0.90	0.4630	3	1.45	0.2313
Sex	1	3.66	0.0560	1	2.52	0.1127	1	0.08	0.7709
Race	1	5.56	0.0185	1	4.16	0.0416	1	1.67	0.1972
Family income	3	0.43	0.7292	3	0.40	0.7511	3	0.04	0.9905
Parental education	3	0.95	0.4166	3	0.98	0.4035	3	2.12	0.0974
Parental activity	3	0.37	0.7720	3	0.27	0.8453	3	2.99	0.0310
Parental BMI risk	3	1.12	0.3402	3	1.08	0.3580	3	1.56	0.1990
Age x sedentary	1	1.13	0.2875	1	0.53	0.4684	1	9.00	0.0028
Age x puberty	4	0.70	0.5909	4	0.87	0.4838	3	1.52	0.2091
Age x sex	1	0.05	0.8307	1	0.02	0.8936	1	0.07	0.7937
Age x race	1	2.13	0.1445	1	1.75	0.1863	1	1.28	0.2585
Age x family income	3	0.33	0.8051	3	0.33	0.8011	3	0.02	0.9950
Age x p_education	3	0.96	0.4105	3	1.02	0.3824	3	2.02	0.1101
Age x p_activity	3	0.56	0.6392	3	0.40	0.7538	3	2.84	0.0376
Age x p_BMI risk	3	1.17	0.3193	3	1.18	0.3168	3	1.74	0.1571

Note. Shaded cell: p<0.05

Table 4.5.6

Relationships between Sedentary Behaviors and Total Physical Activity (Type 3 Test from Full Model)

Effect	TV and Total PA N=4257			Video and Total PA N=4258			Computer and Total PA N=995		
	DF	F	p	DF	F	P	DF	F	p
Age	1	28.77	<.0001	1	37.83	<.0001	1	1.98	0.1599
Sedentary behaviors	1	0.92	0.3377	1	3.25	0.0716	1	7.83	0.0053
Puberty	4	0.63	0.6413	4	0.65	0.6256	3	1.52	0.2120
Sex	1	0.25	0.6169	1	0.06	0.8037	1	0.43	0.5139
Race	1	4.21	0.0404	1	1.73	0.1882	1	1.77	0.1835
Family income	3	0.51	0.6733	3	0.41	0.7435	3	0.53	0.6619
Parental education	3	0.68	0.5668	3	0.59	0.6234	3	1.65	0.1774
Parental activity	3	0.42	0.7372	3	0.19	0.9030	3	2.75	0.0423
Parental BMI risk	3	1.69	0.1663	3	1.53	0.2045	3	1.18	0.3187
Age x sedentary	1	1.02	0.3128	1	0.44	0.5090	1	6.87	0.0090
Age x puberty	4	0.67	0.6111	4	0.69	0.6004	3	1.62	0.1842
Age x sex	1	0.28	0.5998	1	0.97	0.3245	1	1.06	0.3039
Age x race	1	1.34	0.2465	1	0.36	0.5469	1	1.34	0.2470
Age x family income	3	0.23	0.8730	3	0.20	0.8945	3	0.40	0.7496
Age x p_education	3	0.72	0.5424	3	0.63	0.5927	3	1.57	0.1959
Age x p_activity	3	0.69	0.5557	3	0.34	0.7938	3	2.49	0.0598
Age x p_BMI risk	3	1.58	0.1916	3	1.47	0.2200	3	1.30	0.2746

Note. Shaded cell: $p<0.05$

APPENDIX P: Figures (4.5.3 to 4.5.14) and Tables from Research Question 5

Longitudinal Bivariate Relationships between Control Variables and Obesity

Pubertal status had significant main and interaction effects with age on all obesity indicators. Subjects at pubertal stages 1 to 3 increased BMI and waist circumference more rapidly with age compared with those at stages 4 and 5 (Figure 4.5.3 and 4.5.6). Subjects at stages 1 to 3 increased BMI z score with age and those at stages 4 and 5 slightly decreased with age (Figure 4.5.4). The increase of BMI z score at pubertal stage 1 was the fastest. The rate of increase in SSF with age was faster in subjects at stages 1 and 2 compared with those at stages 3 to 5 (Figure 4.5.5).

Sex showed significant main and interaction effects with age on SSF and waist circumference. Figure 4.5.7 shows that girls had higher SSF and that the rate of increase with age in SSF was greater than boys. However, the increasing slope of waist circumference was greater in boys than girls (Figure 4.5.8). Race had significant interaction effect on BMI, BMI z score, and SSF (Figure 4.5.9 to 4.5.11). Black subjects more rapidly increased BMI, BMI z score, and SSF with age than white subjects. Family income had significant interaction effect with age on BMI and significant main and interaction effects with age on SSF. Children from the highest family income group (group 4) had the lowest BMI and the increase in BMI was the lowest (Figure 4.5.12). While children from the highest family income group (group 4) had the lowest SSF, increasing rate of SSF with age was the greatest in the highest income group (Figure 4.5.13).

Parental education and parental activity did not have significant main and interaction effects on obesity. Parental BMI risk showed significant main and interaction effects with age on BMI (Figure 4.5.14). Subjects from the more obese parental group had greater BMI and children from the most obese parental group (group 4) showed the greatest BMI increase with age. In addition, parental BMI risk had a significant main effect on BMI z score and SSF. That is, children from the highest parental BMI risk group (group 4) had the highest BMI z score and SSF regardless of age.

Figure 4.5.3

BMI and Age by Puberty

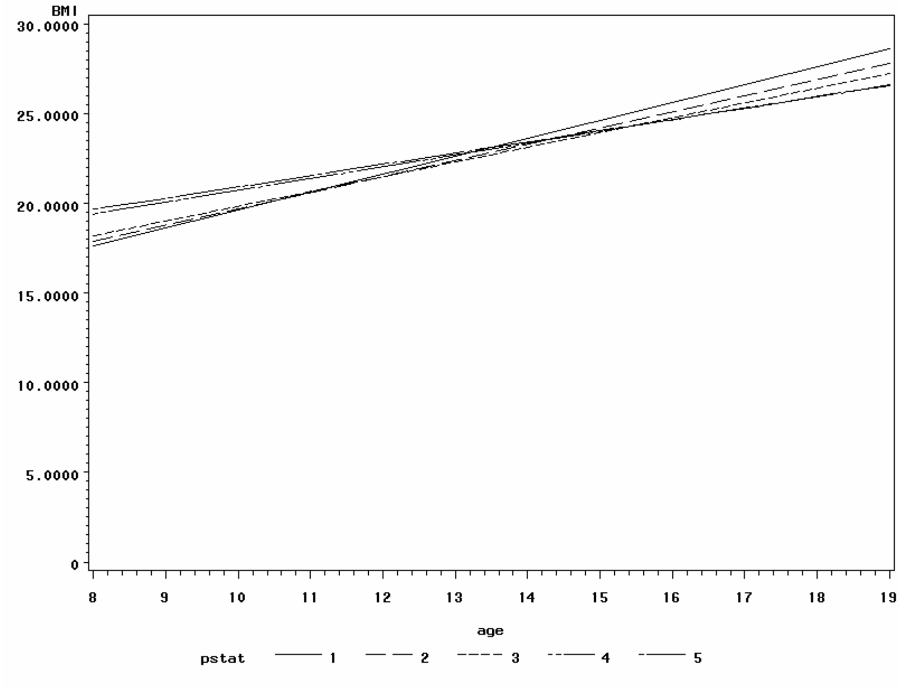


Figure 4.5.4

BMI z and Age by Puberty

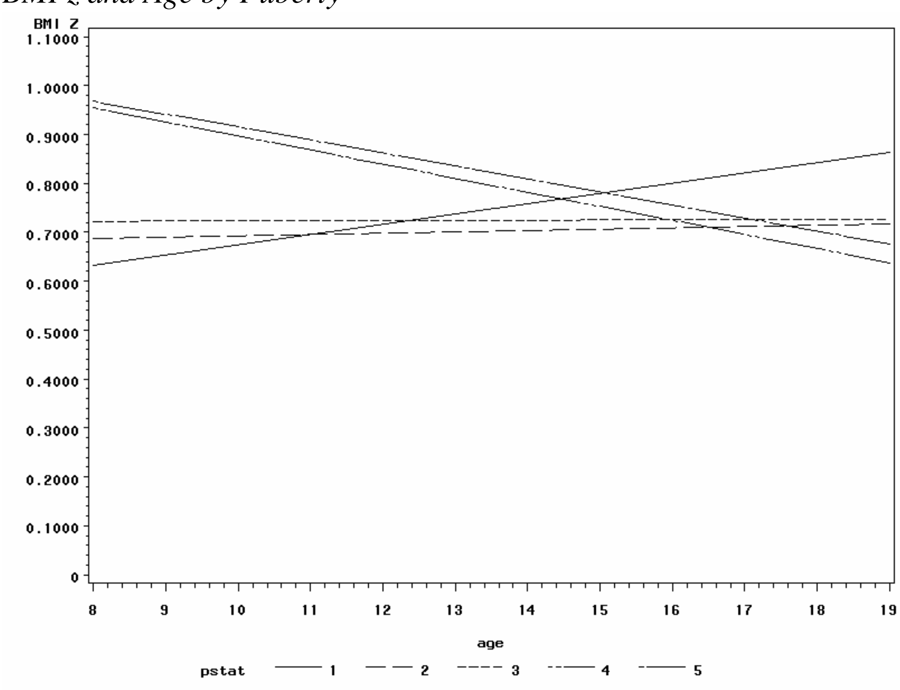


Figure 4.5.5

SSF and Age by Puberty

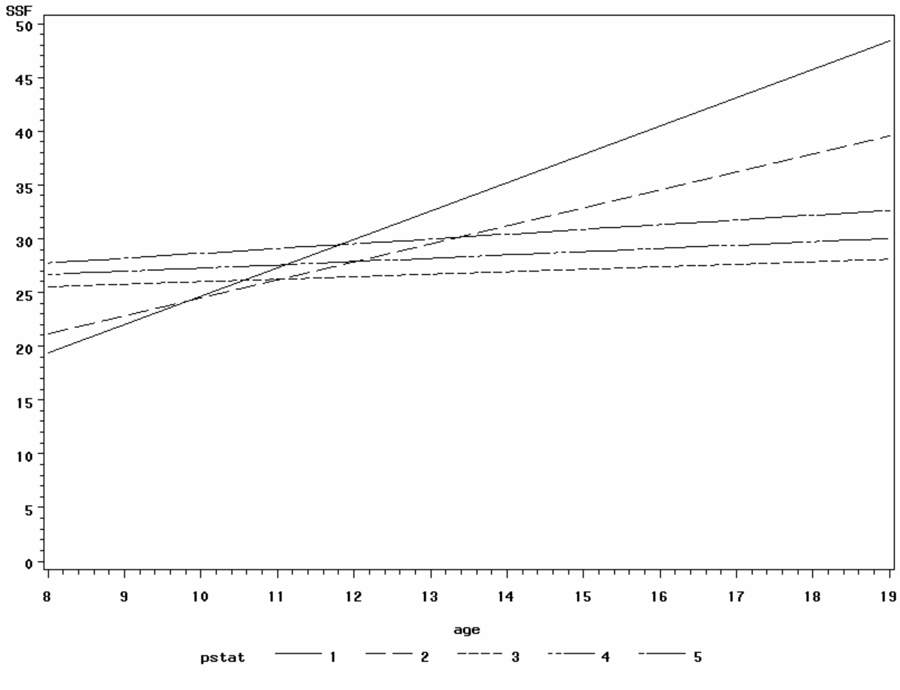


Figure 4.5.6

Waist and Age by Puberty

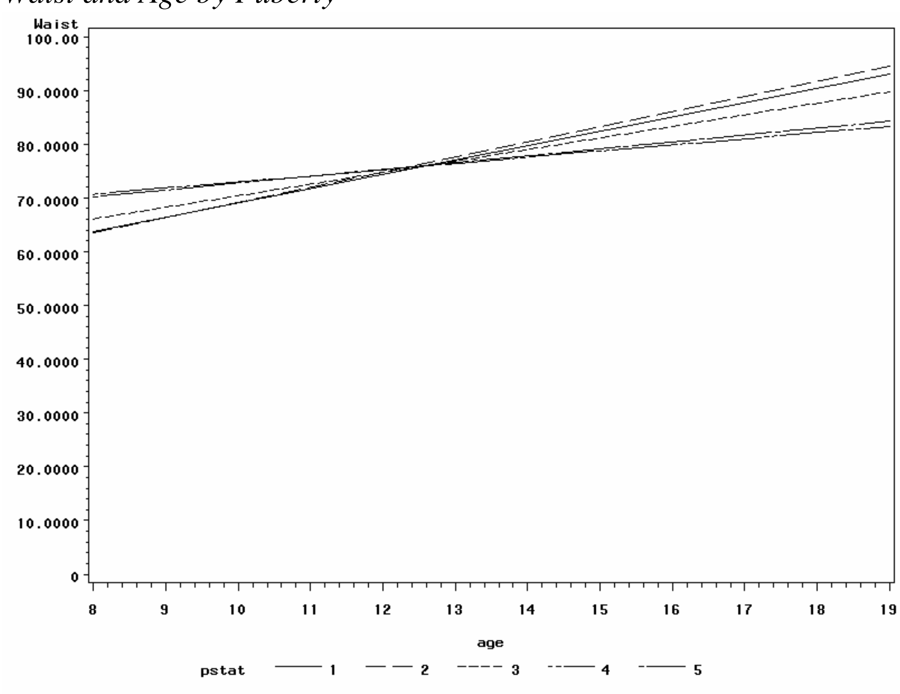


Figure 4.5.7
SSF and Age by Sex

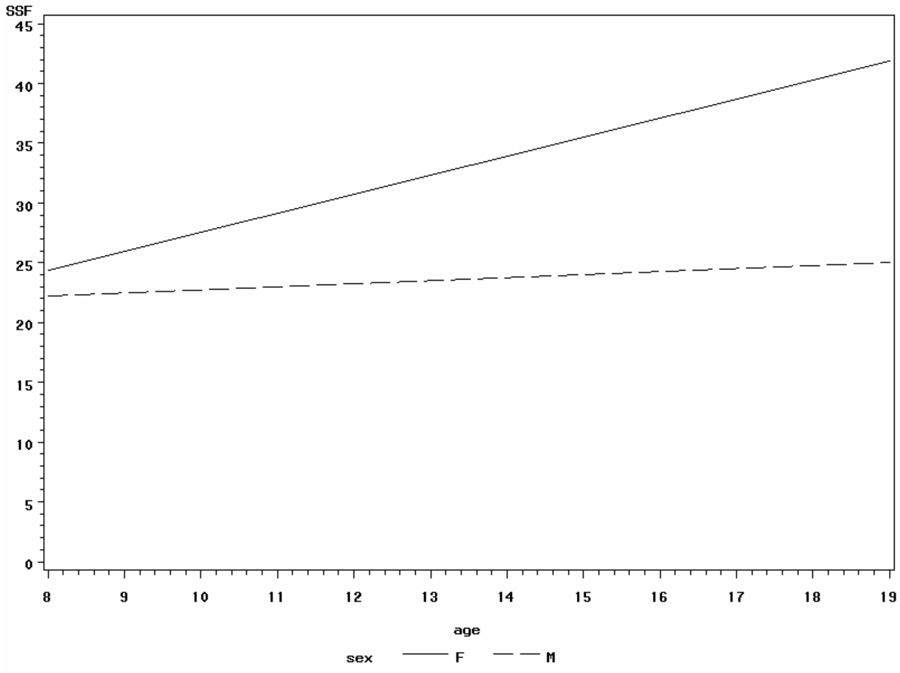


Figure 4.5.8
Waist and Age by Sex

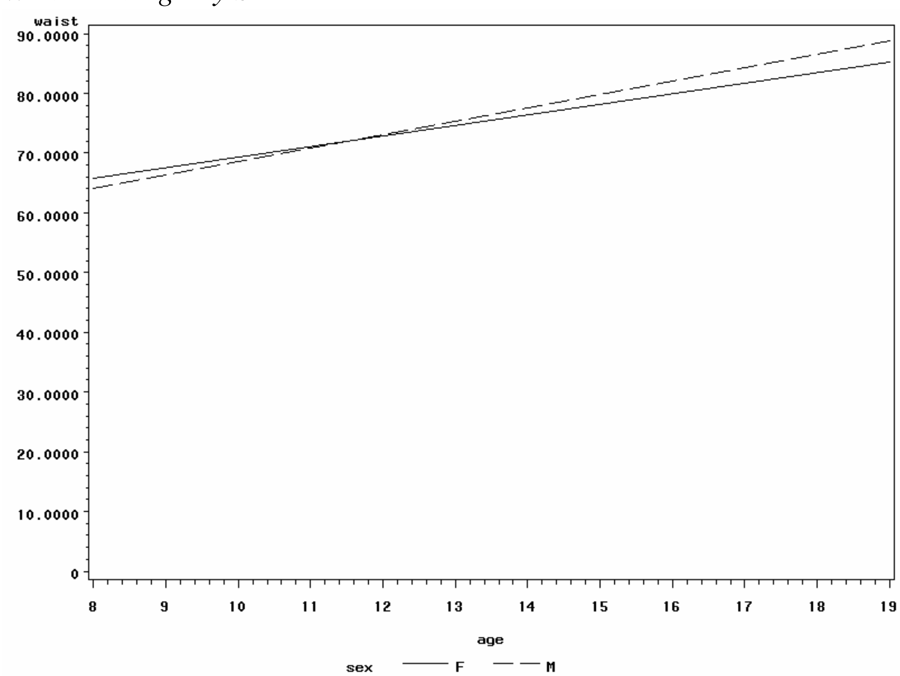


Figure 4.5.9

BMI and Age by Race

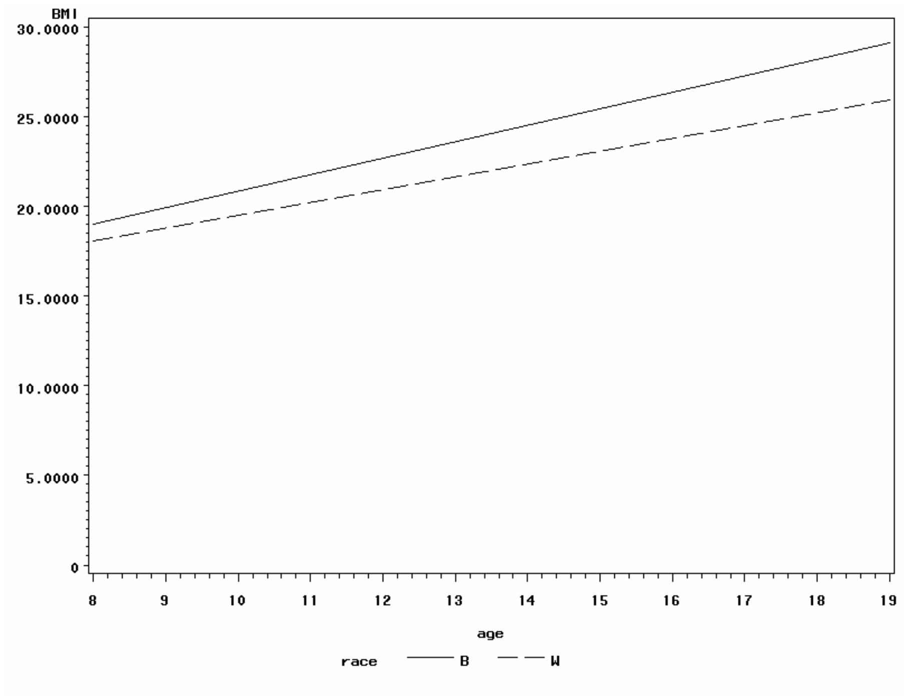


Figure 4.5.10

BMI z score and Age by Race

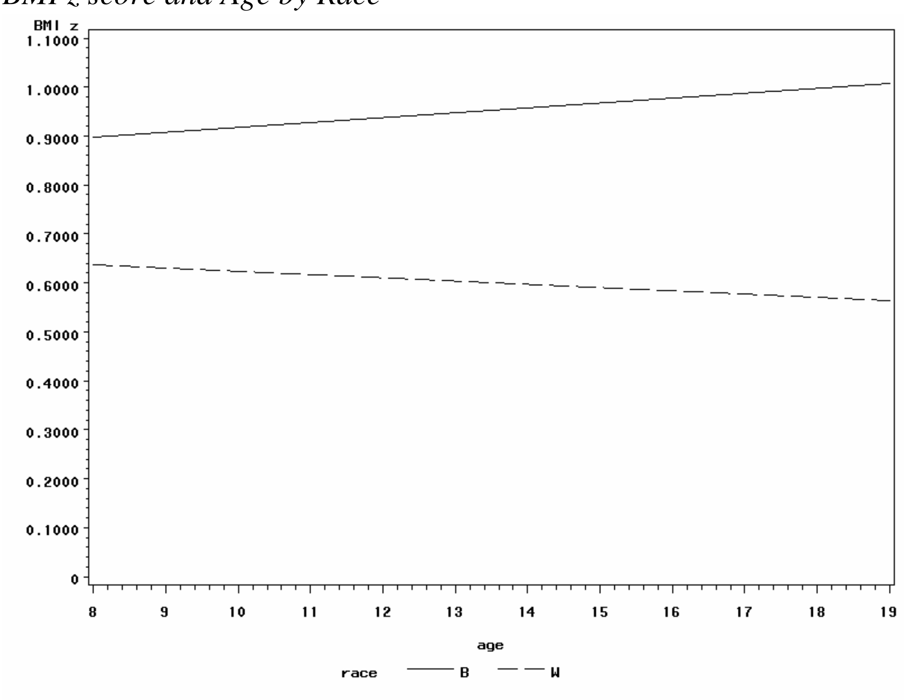


Figure 4.5.11

SSF and Age by Race

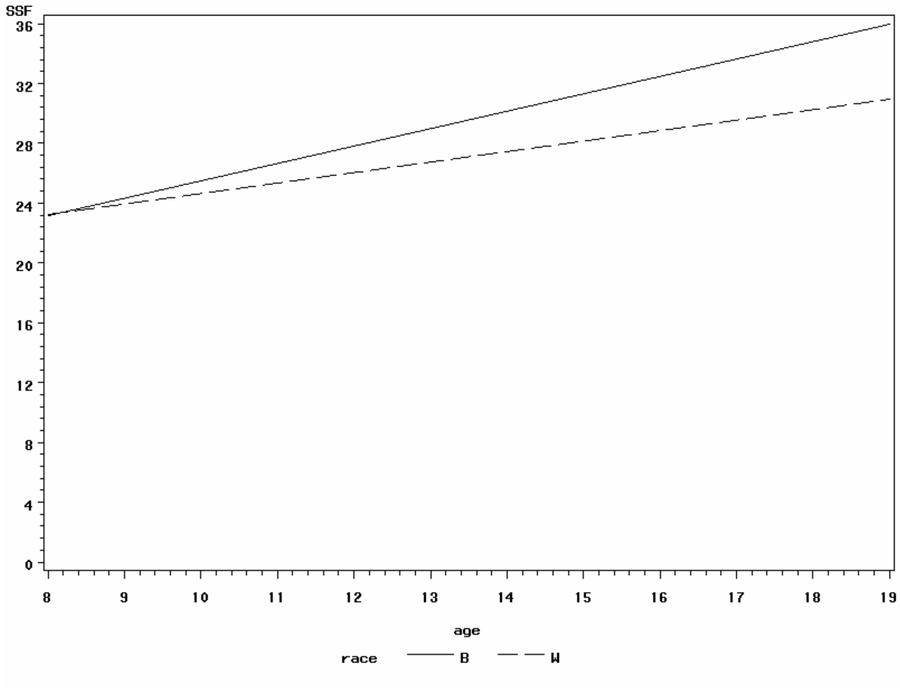


Figure 4.5.12

BMI and Age by Family Income

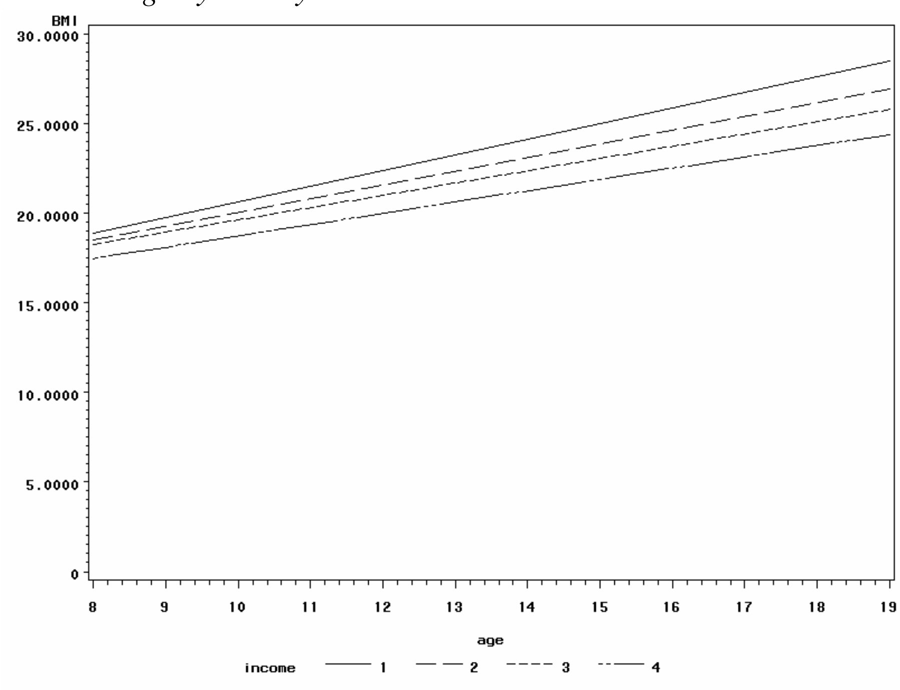


Figure 4.5.13

SSF and Age by Family Income

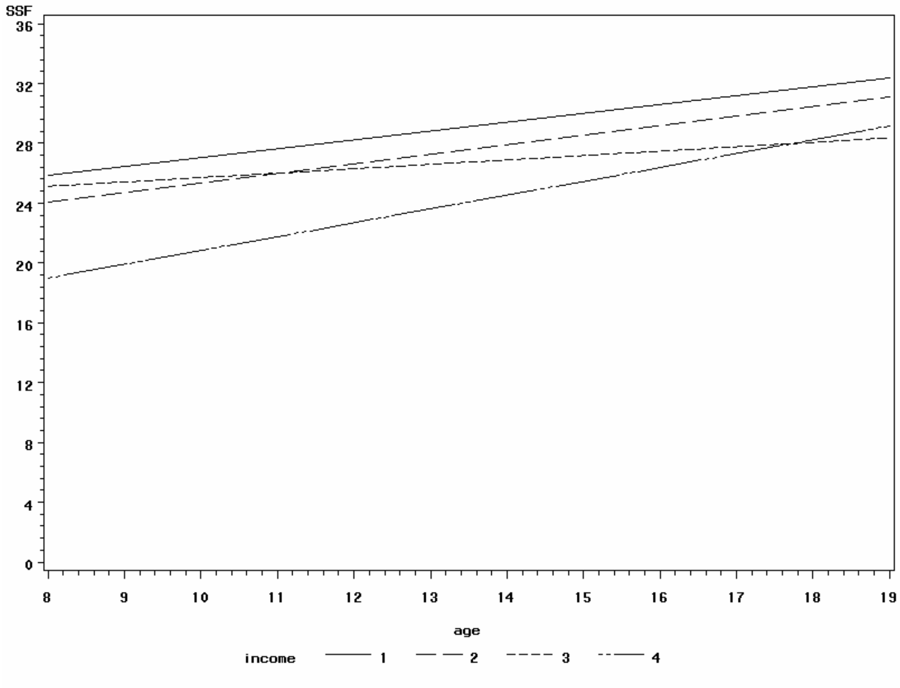


Figure 4.5.14

BMI and Age by Parental BMI risk

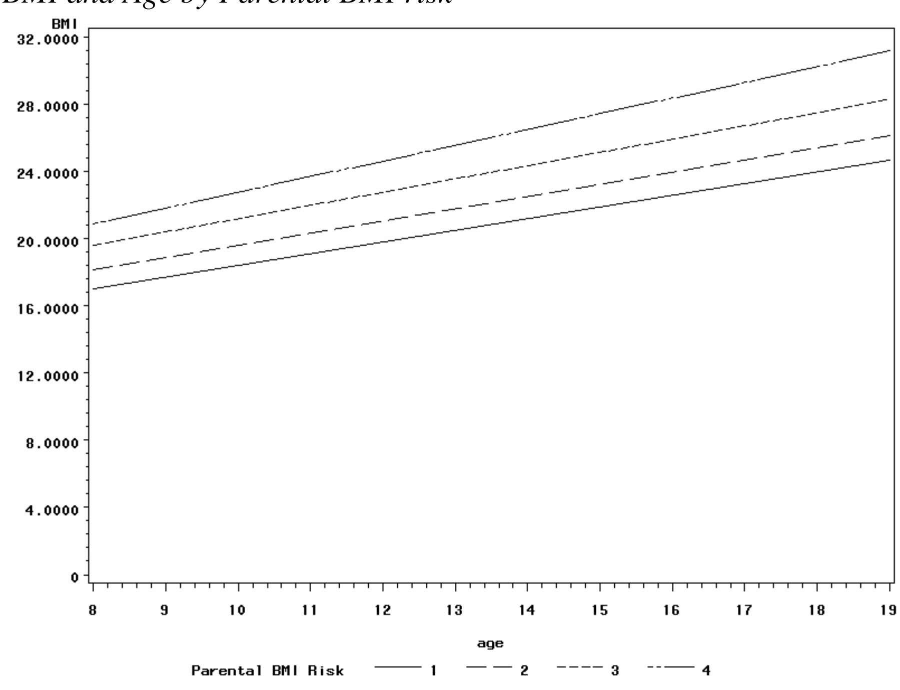


Table 4.6.1

PA Scores and BMI across Age When Controlling for Child Variables

MPA and BMI N=8273				VPA and BMI N=8273			Total PA and BMI N=8273		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		14.56	0.80	Intercept	14.6	0.8	Intercept	14.62	0.80
Age ***		0.56	0.05	Age ***	0.56	0.05	Age ***	0.56	0.05
MPA		-0.004	0.003	VPA	-0.004	0.002	Total PA	-0.002	0.001
Pstat ***	1	-4.26	0.97	Pstat ***	-4.04	0.98	Pstat ***	-4.06	0.99
	2	-3.19	0.86		-2.97	0.87		-3.02	0.88
	3	-2.76	0.76		-2.62	0.77		-2.65	0.77
	4	-0.52	0.70		-0.45	0.70		-0.47	0.70
	5	0	.		0	.		0	.
Sex	F	0.21	0.47	Sex	0.13	0.47	Sex	0.18	0.47
	M	0	.		0	.		0	.
Race	B	0.13	0.47	Race	0.17	0.47	Race	0.16	0.47
	W	0	.		0	.		0	.
Age x MPA		0.0003	0.0003	Age x VPA	0.0003	0.0002	Age x totPA	0.0001	0.0001
Age x pstat ***	1	0.32	0.08	Age x pstat ***	0.30	0.08	Age x pstat ***	0.30	0.08
	2	0.21	0.06		0.2	0.06		0.2	0.06
	3	0.18	0.05		0.17	0.05		0.17	0.05
	4	0.03	0.04		0.03	0.04		0.03	0.04
	5	0	.		0	.		0	.
Age x sex	F	0.02	0.03	Age x sex	0.02	0.03	Age x sex	0.02	0.03
	M	0	.		0	.		0	.
Age x race ***	B	0.14	0.03	Age x race ***	0.13	0.03	Age x race **	0.13	0.03
	W	0	.		0	.		0	.

Note. ** p<0.01, *** p<0.0001

Table 4.6.2

PA Scores and BMI z across Age When Controlling for Child Variables

MPA and BMI z N=8273				VPA and BMI z N=8273			Total PA and BMI z N=8273		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		1.129	0.175	Intercept	1.136	0.175	Intercept	1.139	0.176
Age		-0.033	0.011	Age *	-0.033	0.011	Age *	-0.034	0.011
MPA		-0.001	0.001	VPA *	-0.001	0.0004	Total PA *	-0.001	0.0003
Pstat ***	1	-0.560	0.217	Pstat **	-0.522	0.219	Pstat **	-0.516	0.222
	2	-0.338	0.191		-0.286	0.194		-0.289	0.195
	3	-0.386	0.168		-0.352	0.167		-0.355	0.170
	4	0.020	0.155		0.036	0.155		0.033	0.155
	5	0	.		0	.		0	.
Sex	F	-0.147	0.104	Sex	-0.162	0.104	Sex	-0.151	0.104
	M	0	.		0	.		0	.
Race *	B	0.261	0.104	Race **	0.271	0.1039	Race **	0.271	0.104
	W	0	.		0	.		0	.
Age x MPA		0.0001	0.0001	Age x VPA *	0.0001	0.00003	Age x totPA *	0.0001	0.00002
Age x pstat **	1	0.038	0.017	Age x pstat **	0.033	0.017	Age x pstat **	0.033	0.018
	2	0.016	0.014		0.012	0.014		0.012	0.014
	3	0.022	0.011		0.020	0.011		0.020	0.011
	4	-0.003	0.010		-0.004	0.010		-0.004	0.010
	5	0	.		0	.		0	.
Age x sex	F	0.010	0.007	Age x sex	0.011	0.007	Age x sex	0.010	0.007
	M	0	.		0	.		0	.
Age x race	B	0.006	0.007	Age x race	0.005	0.007	Age x race	0.005	0.007
	W	0	.		0	.		0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Table 4.6.3

PA Scores and Log(SSF) across Age When Controlling for Child Variables

MPA and Log(SSF) N=8243				VPA and Log(SSF) N=8243			Total PA and Log(SSF) N=8243		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		3.3	0.12	Intercept	3.31	0.12	Intercept	3.31	0.12
Age ***		-0.01	0.01	Age ***	-0.01	0.007	Age ***	-0.01	0.01
MPA		-0.0004	0.001	VPA **	-0.001	0.0003	Total PA *	-0.0005	0.0002
Pstat ***	1	-0.82	0.15	Pstat ***	-0.71	0.15	Pstat ***	-0.71	0.15
	2	-0.59	0.13		-0.49	0.14		-0.51	0.14
	3	-0.07	0.12		0.001	0.12		-0.01	0.12
	4	-0.05	0.11		-0.03	0.11		-0.03	0.11
	5	0	.		0	.		0	.
Sex **	F	-0.23	0.06	Sex ***	-0.24	0.06	Sex **	-0.23	0.06
	M	0	.		0	.		0	.
Race	B	-0.01	0.06	Race	0.01	0.06	Race	0.003	0.06
	W	0	.		0	.		0	.
Age x MPA		0.00003	0.00004	Age x VPA**	0.0001	0.00002	Age x totPA *	0.00004	0.00002
Age x pstat ***	1	0.06	0.01	Age x pstat ***	0.06	0.01	Age x pstat ***	0.06	0.01
	2	0.05	0.01		0.04	0.01		0.04	0.01
	3	0.0005	0.01		-0.004	0.01		-0.003	0.01
	4	0.001	0.01		-0.0004	0.01		-0.0001	0.01
	5	0	.		0	.		0	.
Age x sex ***	F	0.04	0.004	Age x sex ***	0.04	0.004	Age x sex ***	0.04	0.004
	M	0	.		0	.		0	.
Age x race	B	0.005	0.004	Age x race	0.004	0.004	Age x race	0.004	0.004
	W	0	.		0	.		0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Table 4.6.4

PA Scores and Waist across Age When Controlling for Child Variables

MPA and Waist N=4585				VPA and Waist N=4585			Total PA and Waist N=8273		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		58.41	3.87	Intercept	59.28	3.87	Intercept	59.51	3.90
Age ***		1.41	0.23	Age ***	1.37	0.23	Age ***	1.34	0.24
MPA		-0.02	0.01	VPA	-0.01	0.01	Total PA	-0.01	0.005
Pstat ***	1	-14.53	4.24	Pstat ***	-14.44	4.28	Pstat ***	-13.49	4.34
	2	-15.55	3.96		-14.88	4.0		-14.29	4.04
	3	-8.68	3.56		-7.83	3.59		-7.60	3.61
	4	2.81	3.39		3.37	3.40		3.32	3.40
	5	0	.		0	.		0	.
Sex **	F	4.98	1.87	Sex *	4.66	1.87	Sex *	4.74	1.87
	M	0	.		0	.		0	.
Race	B	-1.72	1.87	Race	-2.01	1.86	Race	-1.84	1.87
	W	0	.		0	.		0	.
Age x MPA		0.001	0.001	Age x VPA	0.000	0.001	Age x totPA	0.001	0.0004
Age x pstat ***	1	1.14	0.33	Age x pstat ***	1.15	0.33	Age x pstat ***	1.07	0.33
	2	1.26	0.28		1.22	0.28		1.17	0.28
	3	0.69	0.23		0.63	0.23		0.61	0.23
	4	-0.23	0.20		-0.26	0.20		-0.26	0.20
	5	0	.		0	.		0	.
Age x sex **	F	-0.45	0.14	Age x sex **	-0.44	0.14	Age x sex **	-0.44	0.14
	M	0	.		0	.		0	.
Age x race	B	0.21	0.14	Age x race	0.23	0.14	Age x race	0.22	0.14
	W	0	.		0	.		0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Table 4.6.5

PA scores and BMI (Type 3 Test from Full Model)

Effect	MPA and BMI			VPA and BMI			Total PA and BMI		
	DF	F	p	DF	F	p	DF	F	p
Age	1	320.30	<.0001	1	304.30	<.0001	1	258.52	<.0001
PA	1	0.53	0.4659	1	1.88	0.1703	1	1.39	0.2378
Puberty	4	7.33	<.0001	4	6.66	<.0001	4	6.47	<.0001
Sex	1	0.51	0.4768	1	0.40	0.5279	1	0.49	0.4838
Race	1	0.67	0.4143	1	0.87	0.3513	1	0.81	0.3679
Family income	3	0.17	0.9199	3	0.18	0.9123	3	0.17	0.9176
Parental education	3	0.97	0.4077	3	0.96	0.4112	3	0.96	0.4093
Parental activity	3	1.30	0.2737	3	1.29	0.2757	3	1.27	0.2816
Parental BMI risk	3	2.77	0.0403	3	2.72	0.0432	3	2.78	0.0398
Age x PA	1	0.77	0.3808	1	1.62	0.2030	1	1.47	0.2251
Age x puberty	4	6.23	<.0001	4	5.64	0.0002	4	5.50	0.0002
Age x sex	1	0.03	0.8579	1	0.01	0.9160	1	0.03	0.8690
Age x race	1	0.95	0.3306	1	0.74	0.3897	1	0.78	0.3772
Age x family income	3	1.16	0.3216	3	1.23	0.2984	3	1.19	0.3124
Age x p_education	3	0.82	0.4803	3	0.81	0.4863	3	0.82	0.4810
Age x p_activity	3	0.82	0.4847	3	0.83	0.4754	3	0.81	0.4863
Age x p_BMI risk	3	2.30	0.0756	3	2.31	0.0743	3	2.27	0.0789

Note. Shaded cell: p<0.05

Table 4.6.6

PA scores and BMI z score (Type 3 Test from Full Model)

Effect	MPA and BMI z			VPA and BMI z			Total PA and BMI z		
	DF	F	p	DF	F	p	DF	F	p
Age	1	2.21	0.1369	1	4.87	0.0274	1	4.16	0.0415
PA	1	0.21	0.6431	1	3.51	0.0612	1	2.36	0.1244
Puberty	4	4.58	0.0011	4	3.87	0.0039	4	3.90	0.0038
Sex	1	1.19	0.2757	1	1.37	0.2424	1	1.16	0.2809
Race	1	4.39	0.0362	1	5.02	0.0252	1	4.86	0.0276
Family income	3	0.49	0.6860	3	0.47	0.7050	3	0.47	0.7019
Parental education	3	1.92	0.1238	3	1.92	0.1236	3	1.91	0.1262
Parental activity	3	1.31	0.2683	3	1.29	0.2772	3	1.27	0.2822
Parental BMI risk	3	8.83	<.0001	3	8.92	<.0001	3	8.97	<.0001
Age x PA	1	0.59	0.4441	1	4.19	0.0408	1	3.29	0.0696
Age x puberty	4	3.35	0.0096	4	2.84	0.0228	4	2.89	0.0212
Age x sex	1	0.57	0.4499	1	0.76	0.3845	1	0.59	0.4430
Age x race	1	0.31	0.5777	1	0.51	0.4773	1	0.47	0.4939
Age x family income	3	1.22	0.3021	3	1.21	0.3048	3	1.19	0.3135
Age x p_education	3	1.83	0.1388	3	1.83	0.1401	3	1.82	0.1411
Age x p_activity	3	1.09	0.3502	3	1.09	0.3540	3	1.06	0.3643
Age x p_BMI risk	3	0.28	0.8384	3	0.29	0.8316	3	0.30	0.8224

Note. Shaded cell: p<0.05

Table 4.6.7

PA Scores and Log (SSF) (Type 3 Test from Full Model)

Effect	MPA and Log (SSF)			VPA and Log (SSF)			Total PA and Log (SSF)		
	DF	F	p	DF	F	p	DF	F	p
Age	1	26.27	<.0001	1	16.69	<.0001	1	16.05	<.0001
PA	1	0.66	0.4168	1	0.97	0.3255	1	0.28	0.5998
Puberty	4	7.60	<.0001	4	6.43	<.0001	4	6.42	<.0001
Sex	1	14.56	0.0001	1	14.57	0.0001	1	14.21	0.0002
Race	1	0.50	0.4811	1	0.78	0.3760	1	0.63	0.4261
Family income	3	2.42	0.0646	3	2.31	0.0742	3	2.42	0.0639
Parental education	3	1.05	0.3705	3	1.01	0.3890	3	1.02	0.3814
Parental activity	3	2.41	0.0654	3	2.40	0.0658	3	2.38	0.0677
Parental BMI risk	3	8.29	<.0001	3	8.45	<.0001	3	8.45	<.0001
Age x PA	1	0.49	0.4824	1	0.90	0.3421	1	0.52	0.4704
Age x puberty	4	7.37	<.0001	4	6.41	<.0001	4	6.43	<.0001
Age x sex	1	61.74	<.0001	1	61.75	<.0001	1	61.44	<.0001
Age x race	1	0.22	0.6408	1	0.42	0.5182	1	0.33	0.5686
Age x family income	3	1.76	0.1533	3	1.67	0.1721	3	1.75	0.1556
Age x p_education	3	0.96	0.4105	3	0.91	0.4352	3	0.93	0.4236
Age x p_activity	3	1.48	0.2171	3	1.49	0.2155	3	1.46	0.2234
Age x p_BMI risk	3	1.35	0.2555	3	1.43	0.2329	3	1.43	0.2309

Note. Shaded cell: $p<0.05$

Table 4.6.8

PA Scores and Waist (Type 3 Test from Full Model)

	MPA and Waist			VPA and Waist			Total PA and Waist		
Effect	DF	F	p	DF	F	p	DF	F	p
Age	1	79.92	<.0001	1	67.42	<.0001	1	56.31	<.0001
PA	1	0.21	0.6498	1	1.08	0.2980	1	1.53	0.2169
Puberty	4	8.15	<.0001	4	7.25	<.0001	4	6.63	<.0001
Sex	1	3.14	0.0766	1	2.80	0.0945	1	2.86	0.0914
Race	1	0.07	0.7980	1	0.08	0.7790	1	0.06	0.8043
Family income	3	0.71	0.5451	3	0.70	0.5506	3	0.72	0.5375
Parental education	3	0.30	0.8257	3	0.36	0.7787	3	0.34	0.7961
Parental activity	3	1.65	0.1755	3	1.62	0.1825	3	1.66	0.1730
Parental BMI risk	3	0.41	0.7454	3	0.33	0.8072	3	0.36	0.7840
Age x PA	1	0.25	0.6157	1	0.36	0.5507	1	1.04	0.3077
Age x puberty	4	7.97	<.0001	4	7.02	<.0001	4	6.48	<.0001
Age x sex	1	6.16	0.0132	1	5.86	0.0156	1	5.79	0.0162
Age x race	1	0.01	0.9069	1	0.02	0.8831	1	0.01	0.9119
Age x family income	3	1.36	0.2541	3	1.39	0.2456	3	1.40	0.2419
Age x p_education	3	0.22	0.8860	3	0.27	0.8449	3	0.25	0.8588
Age x p_activity	3	1.82	0.1418	3	1.79	0.1471	3	1.83	0.1398
Age x p_BMI risk	3	0.98	0.4010	3	1.16	0.3241	3	1.02	0.3829

Note. Shaded cell: $p<0.05$

APPENDIX Q: Figures (4.6.2 to 4.6.4) and Tables from Research Question 6

Figure 4.6.2

BMI and Age by Hours of Video Games

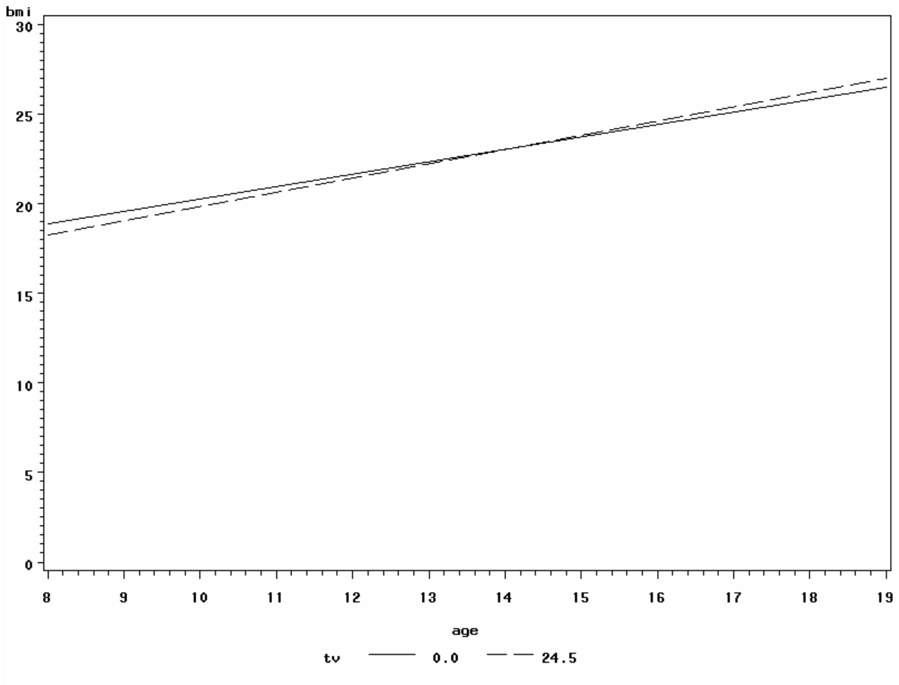


Figure 4.6.3

BMI z score and Age by Hours of Video Games

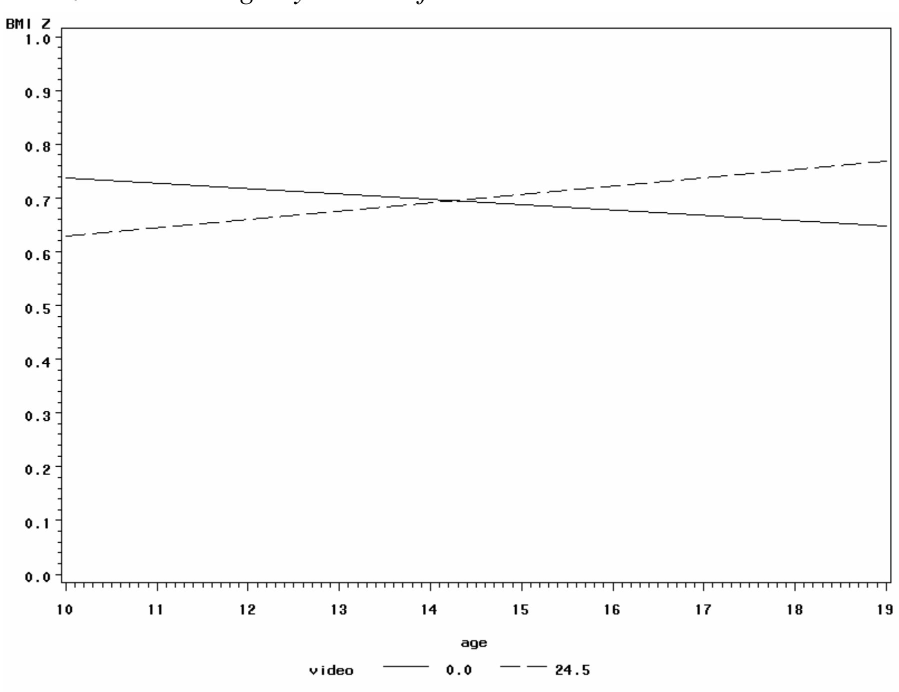


Figure 4.6.4

BMI and Age by Sweet Drink Intakes (Model with Child Variables)

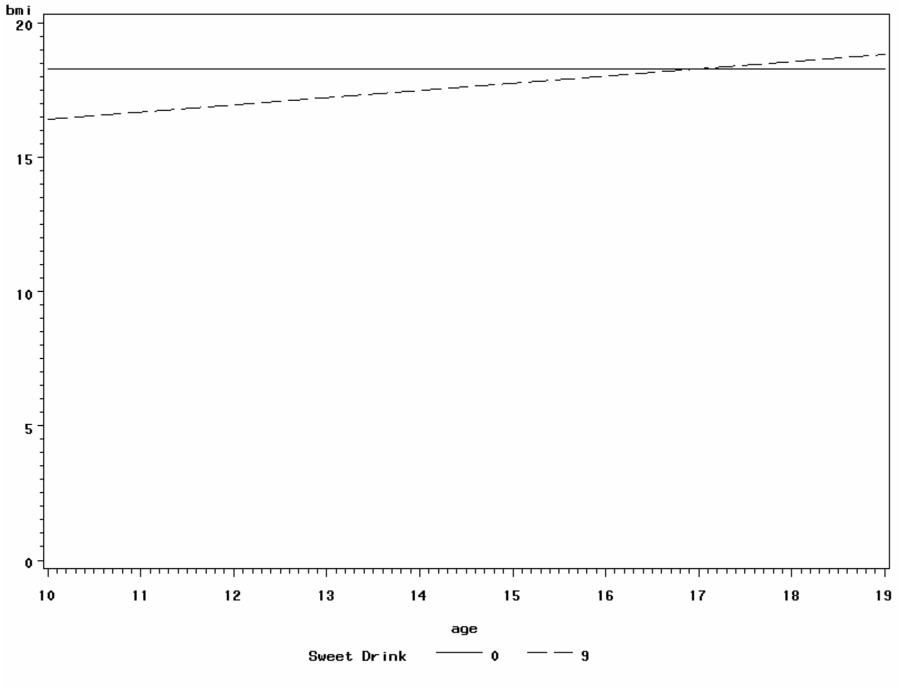


Table 4.7.1 *Sedentary Behaviors and BMI across Age When Controlling for Child Variables*

TV and BMI N=5321				Video and BMI[1] N=2306			Computer and BMI N=1650		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		15.69	1.11	Intercept	18.28	1.95	Intercept	17.27	2.6
Age		0.49	0.07	Age	0.35	0.11	Age	0.40	0.15
TV		-0.04	0.03	Video	-0.003	0.08	Computer	-0.01	0.1
Pstat *	1	-8.80	3.77	Pstat *	43.2	56.85	Pstat	NA	
	2	-6.22	1.62		-7.86	5.71		-3.03	24.29
	3	-4.22	1.02		-5.42	2.11		-4.32	3.23
	4	-0.79	0.86		-0.68	1.63		1.38	1.94
	5	0	.		0	.		0	.
Sex	F	0.08	0.68	Sex	-1.79	1.28	Sex	-0.73	1.89
	M	0	.		0	.		0	.
Race *	B	1.55	0.74	Race **	3.68	1.23	Race	2.12	1.76
	W	0	.		0	.		0	.
				Sweet dr *	-0.51	0.24			
Age x TV		0.003	0.002	Age x video	0.001	0.005	Age x computer	0.001	0.01
Age x pstat ***	1	0.64	0.30	Age x pstat *	-3.63	4.48	Age x pstat	NA	
	2	0.4	0.12		0.45	0.4		0.16	1.56
	3	0.26	0.07		0.31	0.13		0.24	0.2
	4	0.04	0.05		0.01	0.1		-0.11	0.11
	5	0	.		0	.		0	.
Age x sex	F	0.006	0.05	Age x sex	0.12	0.08	Age x sex	0.04	0.11
	M	0	.		0	.		0	.
Age x race	B	0.04	0.05	Age x race	-0.09	0.08	Age x race	0.03	0.1
	W	0	.		0	.		0	.
				Age x sw_dr *	0.03	0.01			

Note. *p <0.5, ** p<0.01, *** p<0.0001   sweet drink[1]: only included in the model with video and BMI

Table 4.7.2

Sedentary Behaviors and BMI z across Age When Controlling for Child Variables

TV and BMI z N=5321				Video and BMI z N=5318			Computer and BMI z N=1496		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		1.51	0.24	Intercept	1.55	0.23	Intercept	2.27	0.54
Age		-0.06	0.02	Age	-0.06	0.01	Age	-0.1	0.03
TV		-0.003	0.01	Video	-0.01	0.01	Comp	-0.03	0.02
Pstat ***	1	-0.8	0.86	Pstat	-0.81	0.86	Pstat	NA	
	2	-1.13	0.36	***	-1.09	0.36		-2.17	4.8
	3	-0.95	0.22		-0.93	0.22		-1.59	0.67
	4	-0.05	0.19		-0.03	0.19		0.005	0.41
	5	0	.		0	.		0	.
Sex *	F	-0.38	0.15	Sex **	-0.41	0.15	Sex	-0.58	0.39
	M	0	.		0	.		0	.
Race *	B	0.33	0.16	Race *	0.35	0.16	Race	0.05	0.35
	W	0	.		0	.		0	.
Age x TV		0.0003	0.0005	Age x video	0.001	0.0005	Age x comp	0.002	0.001
Age x pstat	1	0.04	0.07	Age x pstat	0.04	0.07	Age x pstat	NA	
***	2	0.07	0.03	***	0.06	0.03		0.13	0.31
	3	0.06	0.01		0.05	0.01		0.09	0.04
	4	0.0003	0.01		-0.001	0.01		-0.01	0.02
	5	0	.		0	.		0	.
Age x sex *	F	0.02	0.01	Age x sex *	0.02	0.013	Age x sex	0.03	0.02
	M	0	.		0	.		0	.
Age x race	B	0.002	0.01	Age x race	0.001	0.01	Age x race	0.02	0.02
	W	0	.		0	.		0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Table 4.7.3

Sedentary Behaviors and Log (SSF) across Age When Controlling for Child Variables

TV and Log (SSF) N=5307				Video and Log (SSF) N=5304			Computer and Log (SSF) N=1649		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		3.29	0.16	Intercept	3.39	0.15	Intercept	2.66	0.36
Age		-0.01	0.01	Age	-0.02	0.01	Age	0.02	0.02
TV		0.003	0.005	Video	-0.01	0.005	computer	-0.0004	0.01
Pstat	1	0.12	0.61	Pstat	0.1	0.61	Pstat	NA	
	2	0.11	0.24		0.13	0.24		-0.41	3.01
	3	-0.01	0.15		-0.02	0.14		-0.19	0.45
	4	-0.11	0.12		-0.11	0.12		-0.10	0.28
	5	0	.		0	.		0	.
Sex **	F	-0.32	0.09	Sex **	-0.34	0.09	Sex	-0.11	0.25
	M	0	.		0	.		0	.
Race **	B	0.29	0.1	Race **	0.32	0.1	Race **	0.80	0.23
	W	0	.		0	.		0	.
Age x TV		-0.0001	0.0003	Age x video *	0.001	0.0003	Age*computer	0.0001	0.001
Age x pstat	1	-0.02	0.05	Age x pstat	-0.01	0.05	Age x pstat	NA	
	2	-0.01	0.02		-0.01	0.02		0.02	0.19
	3	-0.01	0.01		-0.005	0.01		0.01	0.03
	4	0.005	0.01		0.005	0.01		0.003	0.02
	5	0	.		0	.		0	.
Age x sex ***	F	0.04	0.01	Age x sex ***	0.05	0.01	Age x sex *	0.03	0.01
	M	0	.		0	.		0	.
Age x race *	B	-0.01	0.01	Age x race *	-0.01	0.01	Age x race **	-0.04	0.01
	W	0	.		0	.		0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Table 4.7.4

Sedentary Behaviors and Waist across Age When Controlling for Child Variables

TV and Waist N=1642				Video and Waist N=1644			Computer and Waist N=1493		
		Estimate	SE		Estimate	SE		Estimate	SE
Intercept		80.18	9.73	Intercept	80.05	8.86	Intercept	84.42	9.24
Age		0.19	0.56	Age	0.19	0.51	Age	-0.06	0.53
TV		-0.22	0.4	Video	-0.21	0.42	computer	-0.51	0.36
Pstat	1	NA	NA	Pstat			Pstat	NA	
	2	-41.12	77.02		-41.87	76.58		-52.14	76.652
	3	-6.8	11.2		-5.16	11.25		-6.42	11.16
	4	0.8	6.98		-0.04	6.96		-1.05	7.02
	5	0	.		0	.		0	.
Sex	F	-1.03	6.32	Sex	0.01	6.82	Sex	0.61	6.41
	M	0	.		0	.		0	.
Race	B	3.01	6.3	Race	1.14	6.01	Race	0.86	5.89
	W	0	.		0	.		0	.
Age x TV		0.01	0.02	Age x video	0.01	0.02	Age x computer	0.03	0.02
Age x pstat	1	NA	NA	Age x pstat			Age x pstat	NA	
	2	2.57	4.94		2.61	4.91		3.26	4.92
	3	0.36	0.68		0.26	0.69		0.33	0.68
	4	-0.18	0.41		-0.14	0.41		-0.08	0.41
	5	0	.		0	.		0	.
Age x sex	F	-0.2	0.37	Age x sex	-0.25	0.4	Age x sex	-0.3	0.37
	M	0	.		0	.		0	.
Age x race	B	-0.04	0.37	Age x race	0.07	0.35	Age x race	0.1	0.34
	W	0	.		0	.		0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

Table 4.7.5

Sedentary Behaviors and BMI (Type 3 Test from Full Model)

Effect	TV and BMI N=4242			Video and BMI N=4242			Computer and BMI N=981		
	DF	F	p	DF	F	p	DF	F	p
Age	1	69.21	<.0001	1	98.22	<.0001	1	4.17	0.0417
Sedentary behaviors	1	2.30	0.1298	1	0.75	0.3876	1	0.01	0.9393
Puberty	4	5.84	0.0001	4	6.33	<.0001	3	0.84	0.4751
Sex	1	0.44	0.5059	1	0.42	0.5163	1	1.25	0.2634
Race	1	1.33	0.2490	1	0.94	0.3318	1	0.56	0.4563
Family income	3	0.80	0.4921	3	0.78	0.5024	3	0.17	0.9134
Parental education	3	1.42	0.2360	3	1.32	0.2648	3	4.10	0.0069
Parental activity	3	1.25	0.2889	3	1.25	0.2902	3	0.49	0.6904
Parental BMI risk	3	2.52	0.0562	3	2.48	0.0596	3	1.01	0.3899
Age x sedentary	1	3.46	0.0629	1	1.02	0.3126	1	0.03	0.8706
Age x puberty	4	4.71	0.0009	4	5.11	0.0004	3	0.86	0.4632
Age x sex	1	0.12	0.7322	1	0.10	0.7531	1	1.26	0.2631
Age x race	1	0.01	0.9059	1	0.02	0.8851	1	1.19	0.2750
Age x family income	3	1.29	0.2744	3	1.37	0.2492	3	0.33	0.8020
Age x p_education	3	0.99	0.3983	3	0.94	0.4204	3	4.76	0.0028
Age x p_activity	3	0.70	0.5517	3	0.67	0.5730	3	0.56	0.6432
Age x p_BMI risk	3	1.85	0.1358	3	2.05	0.1044	3	0.79	0.5009

Note. Shaded cell: $p<0.05$

Table 4.7.6

Sedentary Behaviors and BMI z (Type 3 Test from Full Model)

Effect	TV and BMIz N=4242			Video and BMIz N=4242			Computer and BMIz N=981		
	DF	F	p	DF	F	p	DF	F	p
Age	1	1.59	0.2076	1	1.68	0.1947	1	0.12	0.7310
Sedentary behaviors	1	0.63	0.4274	1	4.46	0.0347	1	0.65	0.4213
Puberty	4	6.75	<.0001	4	6.76	<.0001	3	1.54	0.2076
Sex	1	2.81	0.0940	1	3.82	0.0509	1	0.37	0.5447
Race	1	1.01	0.3157	1	1.13	0.2881	1	0.42	0.5152
Family income	3	0.87	0.4575	3	0.86	0.4627	3	0.05	0.9864
Parental education	3	2.72	0.0429	3	2.69	0.0450	3	2.94	0.0331
Parental activity	3	1.23	0.2980	3	1.31	0.2698	3	1.45	0.2285
Parental BMI risk	3	6.21	0.0003	3	6.16	0.0004	3	0.21	0.8880
Age x sedentary	1	1.08	0.2997	1	4.89	0.0271	1	0.76	0.3850
Age x puberty	4	5.04	0.0005	4	4.97	0.0006	3	1.47	0.2226
Age x sex	1	1.90	0.1686	1	2.76	0.0968	1	0.42	0.5183
Age x race	1	0.01	0.9066	1	0.01	0.9221	1	0.95	0.3300
Age x family income	3	1.26	0.2856	3	1.25	0.2908	3	0.22	0.8798
Age x p_education	3	2.37	0.0683	3	2.35	0.0703	3	3.58	0.0139
Age x p_activity	3	1.02	0.3820	3	1.07	0.3621	3	1.64	0.1783
Age x p_BMI risk	3	0.38	0.7707	3	0.42	0.7420	3	0.92	0.4305

Note. Shaded cell: p<0.05

Table 4.7.7

Sedentary Behaviors and Log(SSF) (Type 3 Test from Full Model)

Effect	TV and Log(SSF) N=4229			Video and Log(SSF) N=4229			Computer and Log(SSF) N=980		
	DF	F	p	DF	F	p	DF	F	p
Age	1	0.03	0.8604	1	0.05	0.8161	1	1.09	0.2966
Sedentary behaviors	1	0.03	0.8691	1	7.10	0.0077	1	0.38	0.5406
Puberty	4	0.65	0.6262	4	0.62	0.6505	3	0.36	0.7827
Sex	1	12.15	0.0005	1	14.79	0.0001	1	0.01	0.9081
Race	1	3.79	0.0518	1	5.16	0.0233	1	0.31	0.5757
Family income	3	3.67	0.0119	3	3.39	0.0173	3	3.99	0.0080
Parental education	3	1.42	0.2360	3	1.28	0.2808	3	0.71	0.5460
Parental activity	3	1.99	0.1141	3	1.91	0.1261	3	0.92	0.4307
Parental BMI risk	3	6.60	0.0002	3	6.44	0.0002	3	1.25	0.2896
Age x sedentary	1	0.02	0.8985	1	9.24	0.0024	1	0.37	0.5413
Age x puberty	4	0.81	0.5168	4	0.75	0.5607	3	0.40	0.7500
Age x sex	1	49.98	<.0001	1	55.28	<.0001	1	1.98	0.1601
Age x race	1	3.01	0.0830	1	3.99	0.0458	1	0.24	0.6267
Age x family income	3	3.18	0.0230	3	2.89	0.0344	3	3.58	0.0139
Age x p_education	3	1.25	0.2899	3	1.13	0.3351	3	0.71	0.5455
Age x p_activity	3	1.49	0.2145	3	1.40	0.2423	3	1.03	0.3790
Age x p_BMI risk	3	1.57	0.1957	3	1.50	0.2120	3	0.84	0.4725

Note. Shaded cell: p<0.05

Table 4.7.8

Sedentary Behaviors and Waist (Type 3 Test from Full Model)

Effect	TV and Waist N=976			Video and Waist N=978			Computer and Waist N=980		
	DF	F	p	DF	F	p	DF	F	p
Age	1	0.08	0.7734	1	0.25	0.6205	1	0.46	0.4959
Sedentary behaviors	1	1.92	0.1660	1	3.78	0.0523	1	1.30	0.2556
Puberty	3	0.54	0.6541	3	0.25	0.8638	3	0.53	0.6607
Sex	1	2.70	0.1011	1	1.45	0.2285	1	3.38	0.0665
Race	1	2.12	0.1459	1	3.12	0.0781	1	2.73	0.0992
Family income	3	2.10	0.0991	3	2.07	0.1039	3	1.80	0.1465
Parental education	3	1.53	0.2050	3	1.63	0.1812	3	1.41	0.2403
Parental activity	3	1.20	0.3099	3	1.06	0.3668	3	1.04	0.3740
Parental BMI risk	3	0.90	0.4407	3	1.08	0.3570	3	1.18	0.3162
Age x sedentary	1	1.84	0.1758	1	4.06	0.0444	1	1.41	0.2363
Age x puberty	3	0.44	0.7249	3	0.18	0.9112	3	0.42	0.7376
Age x sex	1	4.72	0.0303	1	2.85	0.0919	1	5.60	0.0183
Age x race	1	1.64	0.2003	1	2.57	0.1097	1	2.21	0.1374
Age x family income	3	2.52	0.0569	3	2.45	0.0628	3	2.26	0.0803
Age x p_education	3	1.46	0.2233	3	1.60	0.1885	3	1.36	0.2550
Age x p_activity	3	1.29	0.2775	3	1.14	0.3324	3	1.13	0.3357
Age x p_BMI risk	3	1.49	0.2177	3	1.74	0.1575	3	1.76	0.1547

Note. Shaded cell: $p<0.05$

APPENDIX R: Figures (4.7.3 to 4.7.4) and Tables from Research Question 7

Figure 4.7.3

BMI and VPA by Computer Use

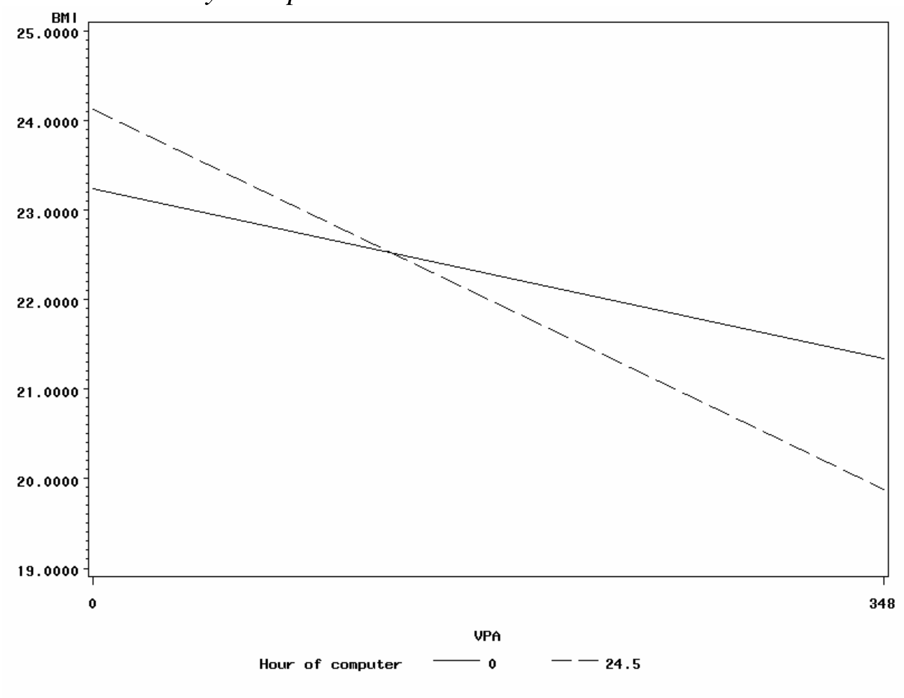


Figure 4.7.4

Waist and Total PA by Computer Use

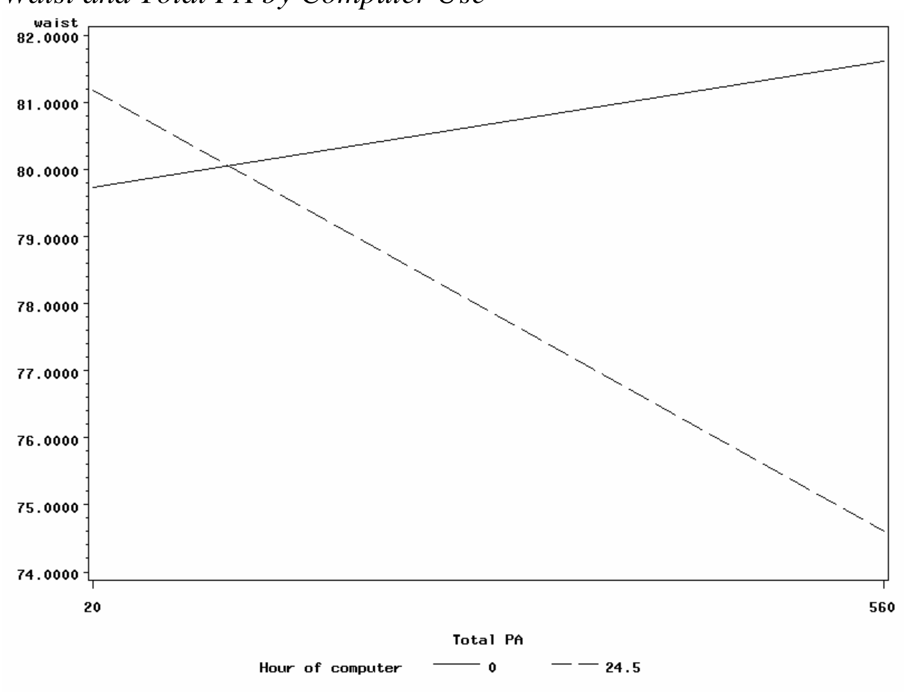


Table 4.8.1

Interaction between MPA and Computer on Log(SSF) (Model with Child Variables)

Log(SSF) N=1590			
		Estimate	SE
Intercept		2.56	0.39
Age		0.03	0.02
MPA		-0.0004	0.004
Computer		0.01	0.02
MPA x computer *		-0.0001	0.00004
Pstat	2	-0.04	3.02
	3	-0.04	0.46
	4	-0.00804	0.29
	5	0	.
Sex	F	-0.09853	0.26
	M	0	.
Race ***	B	0.9149	0.23
	W	0	.
MPA x age		0.000013	0.0002
Computer x age		-0.00037	0.001
Age x pstat	2	-0.00161	0.19
	3	-0.00109	0.03
	4	-0.00285	0.02
	5	0	.
Age x sex *	F	0.02978	0.01
	M	0	.
Age x race **	B	-0.04727	0.01
	W	0	.

Note. *p <0.5, ** p<0.01, *** p<0.0001

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