A LONGITUDINAL STUDY EXAMINING THE RELATION OF PHYSICAL ACTIVITY ON WEIGHT STATUS DURING ADOLESCENCE

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Objective. The objective of this analysis was to examine the relation of physical activity (PA) to weight status in a sample of adolescents. *Study Design*. A four year longitudinal study was conducted. *Methods*. A diverse sample of 1098 adolescents aged 11-16 years was assessed annually over four years. Height and weight were measured. BMI and weight status category were calculated. Physical activity was assessed via a questionnaire to determine the hours per week of activity over the past year. A generalized mixed model statistical approach was used to test the main hypothesis. *Results*. A decline in physical activity and an increase in BMI was found among males and females ($p<0.01$). Significant differences regarding the amount of physical activity between gender, race and SES levels was also found ($p<0.05$). Overall, the highest amount of physical activity was reported by males, Caucasians and those in the high SES group. As for weight status, males were more often categorized as "at risk" and "overweight" compared to females ($p < 0.05$). There was insufficient evidence to support the main hypothesis that physical activity affected weight status. Thus the amount of physical activity one participated in during each study year, did not increase the odds of being categorized as "at risk" or "overweight" compared to a "healthy weight". Nor did the amount of physical activity one participated in during the previous year, increase the odds of being categorized as "at risk" or "overweight" compared to a being categorized as a "healthy weight" the following year. *Conclusions*. The results of this study do not support the hypothesis that decreasing physical activity during adolescence is related to change in weight status. Conclusions can be made however, regarding the relationships between the covariates and both the amount of physical activity and weight status category. Overall, males, Caucasians and those in the high SES group report higher amounts of physical activity. Males were more often categorized in the higher weight status categories compared to females.

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PREFACE

I am especially indebted to my research advisor, Dr. Deborah Aaron, for her dedication to mentoring me during a challenging time in her life. She has always challenged me to continually improve as a researcher, by having such high standards for my work which has enabled me to develop a strong research base from which I will continue to grow. She has been and always will be someone that I look up to with great respect and admiration.

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I thank my parents, David and Jean Landsbaugh, for their love and support these past 28 years. They always believed in me and made sure that I always believed in myself. Lastly, I would like to express my sincerest thanks to my best friend, Joel Kaar. I am grateful that he is a part of my life and for being the person that always encourages me to challenge myself. He has truly been an inspiration in my life by helping me discover who I am and most importantly, who I want to become.

1.0 INTRODUCTION

The purpose of this proposed research was to determine the relation between physical activity and weight status among adolescents. This chapter is composed of the following sections: (1.1) Rationale, (1.2) Purpose, (1.3) Significance, (1.4) Specific Aims, and (1.5) Research Hypotheses.

1.1 RATIONALE

In 2006, the National Health and Nutrition Examination Survey (NHANES) data reported that 33.6% of children, ages 2-19 years, were at risk for overweight, while 17.1% were overweight.[1] There are many negative medical and psychosocial consequences associated with the prevalence of adolescence being overweight.[2, 3] Overweight children are at a high risk for many medical complications which used to be only found among adults including; hypertension,[4-6] hyperlipidemia,[7-9] diabetes,[4, 8] and sleep apnea.[10] There are psychosocial consequences associated with overweight children.[3, 11] Overweight children may not be as popular among their peers as non-overweight children[12] and can be subjected to being teased or ridiculed about their weight issues.[13]

Previous research has shown that several factors may increase the likelihood of being overweight. Studies have reported that twice as many adolescents from low income households are overweight compared to adolescents from middle- and higher-income households.[14, 15]

Gender and racial differences have also been reported. Females in general are more overweight than males and African American and Hispanic individuals have the highest prevalence of being overweight.[14, 16-18]

Numerous factors have been identified in contributing to the increase of obesity including; parental weight status, birth weight, diet and physical activity.[19] Examining physical activity more closely, Healthy People 2010 reported that only 27% of adolescents in 1999 engaged in the amount of recommended moderate physical activity (30 minutes, 5 or more days/week).[14] Engaging in physical activity has been associated with many health benefits in children,[20] such as assisting in overall weight control[21-23] and the reduction of risk factors for chronic diseases including; triglycerides,[7, 8] HDL cholesterol,[9] glucose,[4] insulin,[8] hypertension,[4-6] and abdominal adiposity.[21, 24] Physical activity has also been shown to improve psychological[25] & general well-being,[26] and overall positive mood.[26]

The amount of physical activity one participates in can be influenced by a variety of factors. Statistics show gender, racial and social economic status (SES) differences in regards to physical activity. The National Center for Health Statistics (NCHS), found that females are less active than males, people with lower income and less education are less active than people with higher income and higher education, as well as African American and Hispanics having the least amount of physical activity among all races.[14]

Not only do the national health statistics confirm these discrepancies, numerous research studies have found that males are more physically active than females at all ages.[27-33] More over, racial differences are common in the physical activity literature regarding amount and type of physical activity. Caucasian children are often reported as having more physical activity when compared to African American children.[14, 33-36] Studies have also shown that African American and Hispanic children are less likely to participate in organized sports compared to Caucasian individuals.[35] Studies have also found that as the level of SES increases, the amount of physical activity reported, decreases.[16, 33]

With the increasing prevalence of obesity among adolescence,[37] and the well known impact of this weight in regards to risk factors for various chronic diseases that start in adolescence,[10, 38-40] research needs to investigate clear mechanisms that have the potential to stop the progression of abnormal weight gain throughout adolescence. Once such mechanism, the relation of physical activity to weight status, as research has found significant evidence that PA declines during adolescence.[27-30, 34, 41, 42] This analysis adds to the current literature as it investigated how the decline of physical activity may affect weight status over a four year time period using a large diverse sample of adolescents.

1.2 PURPOSE

The objective of this analysis was to examine the relation of physical activity to weight status in a sample of adolescents over a four year time period. Weight status was defined as normal weight, at risk for overweight, or overweight based on the Centers for Disease Control and Prevention criteria for children and adolescents.

1.3 SIGNIFICANCE

The co-morbidities related to pediatric obesity are serious and there is a need to develop obesity prevention programs. From a prevention standpoint, 79% of adolescents who are overweight are considered at risk of becoming overweight as adults.[43] This statistic illustrates the importance of conducting research in pediatric populations to prevent unhealthy habits, such as lack of physical activity. Current methods in combating obesity in the pediatric population have shown little progress towards curving the epidemic. A close examination of the relationship between lifestyle behaviors, namely levels of physical activity, and changes in weight status would contribute to developing more effective interventions.

1.4 SPECIFIC AIMS

The primary aim of the proposed research was the following:

1. To identify the relation between physical activity and weight status.

The secondary aims of the proposed research include the following:

1. To identify *gender* differences associated with the relation between physical activity and weight status.
2. To identify *ethnic* differences associated with the relation between physical activity and weight status.
3. To identify *socioeconomic* differences associated with the relation between physical activity and weight status.

1.5 RESEARCH HYPOTHESES

It was hypothesized that:

1. Decreased physical activity over four years will increase the likelihood that an adolescent will be categorized as at risk for overweight or overweight.

2.0 REVIEW OF RELATED LITERATURE

The purpose of this study was to examine the relation of physical activity levels to weight status in adolescents over a four year time period. This chapter will review the related literature to this topic. This section is composed of the following sections: (2.1) Physical Activity in Adolescence, (2.2) Obesity in Adolescence, (2.3) Adolescents Physical Activity Levels in Relation to BMI, and (2.4) Prevention of Obesity in Adolescence.

2.1 PHYSICAL ACTIVITY IN ADOLESCENCE

2.1.1 Defining and measuring physical activity

The definition of physical activity and exercise are often used interchangeably, however are defined separately. Physical activity is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure."[44] Exercise on the other hand is defined as "planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness."[44] Below is a table derived from Caspersen et al describing the distinguishing characteristics between physical activity and exercise.[44]

Table 1: Defining characteristics of physical activity and exercise

Physical Activity	Exercise
1. Bodily movement via skeletal muscles. 2. Results in energy expenditure. 3. Energy expenditure (kilo-calories) varies continuously from low to high. 4. Positively correlated with physical fitness.	1. Bodily movement via skeletal muscles. 2. Results in energy expenditure. 3. Energy expenditure (kilo-calories) varies continuously from low to high. 4. Very positively correlated with physical fitness. 5. Planned, structured, and repetitive bodily movement. 6. An objective is to improve or maintain physical fitness component(s).

Measuring physical activity and exercise is considered time consuming and technically challenging. Several methods to assess physical activity, with a variety of outcome variables have been explored. The following table summarizes the outcome measures derived from physical activity assessments, based on the instrument used.[45] All methods include the following dimensions: frequency, intensity, duration and energy expenditure.

Table 2: Existing measurement tools for physical activity and their corresponding outcome variables

Method of Measurement	Units of Measurement	Output Measure
Self-report	Bouts of physical activity	• # of bouts > criterion level • # or % of bouts • # of min > criterion level • Estimates based on METS
Activity monitors or motion sensors	Movement controls	• # of bouts > criterion level • Average counts per day or interval • # of min > criterion level • Estimates from calibration equation
Heart rate (HR)	Beats (b-min^{-1})	• # of bouts > criterion level • Average HR per day or interval • # of min > criterion level • Estimates from calibration equation
Pedometers	Step counts	• # of steps taken • Estimates from calibration equation
Direct observation	Activity rating	• # of bouts > criterion level • # or % of bouts • # of min > criterion level • Estimates based on METS
Indirect calorimetry	O_2 consumption	• # of bouts > criterion level • Average VO_2 level • Monitored time > threshold • Total energy expenditure
Doubly labeled water	CO_2 production	• Total energy expenditure

Each technique has advantages and disadvantages which will be discussed below. The most reliable methods include: direct observation, doubly labeled water measurement, and indirect calorimetry. Other methods include both subjective (self-report) and objective (accelerometers, heart rate monitors, and pedometers) measures.

Doubly Labeled Water (DLW)

DLW technique measures the rate at which metabolic processes in the body are used to meet the energy demand of physical activity. In order to measure energy expenditure two stable isotopes, deuterium and oxygen-18, are given orally. The concentration of these isotopes are then measured in the urine. From this information the total amount of carbon dioxide production can be measured.[45] DLW is considered the most accurate method of measuring energy expenditure through free-living physical activity. Disadvantages include the high cost of the measurement.

Indirect Calorimetry

Indirect calorimetry uses O_2 consumption and CO_2 production to calculate energy expenditure (EE). This technique is more often used as a validation measure against other more objective measures of physical activity (i.e. activity and heart monitors, pedometers) Advantages are that this technique is both valid and accurate to measure short term EE. Disadvantages are the high cost to perform the test and the limitation of mode.[45]

Direct Observation

Direct observation is often used to assess physical activity in children.[45] This technique is able to "classify free living physical activity behaviors into distinct categories that can be quantified and analyzed in greater detail."[45] The advantage of direct observation is that it enables one to individualize the type of activity, when and where the activity occurs, and who is doing the activity. Disadvantages are that this measure can be time consuming both in data collection and data analysis in addition to time needed to train the observers to record the activity.

Self-Report

Completion of questionnaires is an inexpensive and simple way to measure physical activity. Questionnaires have been validated for various types of activity, lengths of time, and age groups. All of these features make self-report questionnaires very appealing to researchers. The disadvantage is the reliability and validity issues with each questionnaire along with cognitive issues regarding the subjects.[46-49] The accuracy of self-report questionnaires is adversely affected by poor comprehension of questions and poor recall of recently completed activities.[49] Selection of an age appropriate questionnaire can limit the inaccuracies along with proper implementation of the questions.

Each self-report questionnaire is tested against a preexisting PA measurement in order to test if the tool is a valid measure. Questionnaires are also tested for reliability to ensure the measurement is consistent by providing the same results under the same circumstances. All questionnaires have their own guidelines for the specific process to implement and score the questionnaire. Review articles have been published in order to determine which questionnaires have the highest correlations in comparison to objective tools such as the pedometer or accelerometer.[46-48] The most widely used questionnaire for children and adolescents, known as the Past Day Physical Activity Recall (PDPAR), has a coefficient correlation of 0.77 and 0.88 with a pedometer and an accelerometer, respectively.[48] A disadvantage of the PDPAR is that it was validated as an interviewer-administered questionnaire, therefore, it is very expensive and requires an extensive amount of time from research staff to administer to each subject.

For the current study, the Modifiable Activity Questionnaire for Adolescents (MAQ) was used which can be self-administered with supervision. The MAQ has been found to be both reproducible and valid in measuring physical activity in an adolescent population.[50] This questionnaire has been tested against the 7-day recall and was found to be correlated in males (r = 0.55-0.67) and females (r = 0.73-0.83). This questionnaire examines both recreational and leisure time activities one has participated in with a minimum of ten times over the past year to estimate the total hrs/wk of overall leisure time activity in the past year.

Activity and Heart Rate Monitors

Activity monitors (often referred to as accelerometers) assess total body movement by using acceleration. Acceleration is defined as "the change in velocity over time…expressed in terms of multiples of gravitational force."[45] Movement is measured by various sensors on the device. Information from the sensors is incorporated into mathematical equations that predict energy expenditure. Advantages are that this measure can be useful for laboratory and field settings, and are relatively easy to use to collect physical activity data. Limitations are that these monitors can be costly and use would be limited to studies with small sample size. These monitors have also been found to be less accurate during activities that involve multidimensional movements (i.e. swimming, upper body activities).[45]

Heart rate monitors are also an option to measure physical activity. These devices provide not only a useful physiological tool, they also have been associated with measuring energy expenditure.[45] Data using heart rate monitors can be collected and analyzed very easily, which makes them ideal for both laboratory and field settings. This measure, like the other monitors, has limitations which include cost, activity/sport specific, and uncertainty of mathematical equations in predicting energy expenditure from data provided.

Pedometers

Pedometers, which record the number of steps taken each day, can be used to measure physical activity. Pedometers are an inexpensive tool to measure physical activity levels. These are useful for large sample size research, can be administrated in a variety of settings, and are suitable for all age groups. Problems exist with pedometers as well as any other electronic device; they can break easily or not function properly. These measures are also limited in the mode of physical activity they can assess. They can not assess running, biking, swimming, etc.

2.1.2 Relation of physical activity to health in children and adolescents

Numerous health benefits have been associated with engaging in physical activity.[20] Physical activity has been linked to improvements in several fitness components: cardiovascular, strength, muscular endurance, flexibility, and body composition. [20, 23, 51] Physical activity also helps prevent diabetes and heart disease. Disease prevention has also been associated with a physically active lifestyle including the reduction of risk factors for chronic diseases. Potential disease risk factors that can be improved by physical activity include; triglycerides,[7, 8] HDL cholesterol,[9] glucose,[4] insulin,[8] hypertension,[4-6] and abdominal adiposity.[21, 24] Physical activity has also been shown to improve psychological[25] & general well-being,[26] and overall positive mood.[26] Physical activity has also been associated with positive health behavior including: smoking,[22, 23] diet,[23] and overall academic performance.[52] Finally, physical activity has been found to assist in overall weight control.[21-23] All of these benefits are directly associated with the numerous medical complications children experience when overweight including; hyperlipidemia,[7-9] hypertension,[4-6] diabetes,[4, 8] and the psychosocial complications (teasing and being less popular).[3, 11-13]

2.1.3 Physical activity recommendations

The specific amount of physical activity needed for good health is not known.[53] It is possible that the gap in knowledge in this regard is partly responsible for the lack of uniformity in physical activity recommendations. (See Table 3.) As a result, several recommendations for physical activity have been established. The variability in recommendations may be attributed to differences in methodology used to collect data and/or specific organizations/agencies focusing on a single health outcome only. [54]

Table 3: Current physical activity recommendations

Agency	Current Physical Activity Recommendation for Children and Adolescents
Surgeon General , US Department of Health and Human Services (USDHHS), 1996	"It is recommended that Americans accumulate at least …60 minutes (children) of moderate physical activity most days of the week."[55]
Centers for Disease Control (CDC), Dietary Guidelines for Americans, 2005	"It is recommended that children and adolescents participate in at least 60 minutes of moderate intensity physical activity most days of the week, preferably daily." [14]
American Heart Association (AHA), 1996	"All children age 2 and older should participate in at least 30 minutes of enjoyable, moderate intensity activities per day. They also should perform at least 30 minutes of vigorous physical activities at least 3-4 days each week to achieve and maintain a good level of cardiorespiratory fitness."[56]
Institute of Medicine (IOM), 2002	"For children…60 minutes of daily moderate intensity physical activity…(e.g., walking/jogging at 4 to 5 mph)."[57]

2.1.4 Physical activity throughout adolescence

Research has shown that young children who are very physically active are likely to remain as active several years later.[42] Similarly, less active children are likely to remain less active.[34] Examinations of activity patterns in children as young as kindergarten to 3rd grade have been conducted to examine earlier declines in physical activity.[58] Janz et al. used accelerometers in a cohort of 378 children to measure physical activity and classify the level of physical activity: inactive, moderate, or vigorous.[58] Males and females with the highest level of overall activity at baseline (defined as the sum of all accelerometer movement counts/minutes the accelerometer was worn) were 3.9 times more likely to remain in the highest level of overall activity at the 3 year follow-up. The females and males in the highest levels of vigorous and moderate activity in kindergarten were 3.5 and 3.6 times more likely to remain at that level in third grade. The least active males and females at baseline were found respectively to be 4.3 and 5.8 times more likely to be in the highest level of sedentary time three years later. In summary, children who engage in an active lifestyle continue to be active as they grow older.

A major public health concern in the United States is the decline of physical activity among adolescents.[14] Merely 27% of adolescents in 1999 engaged in the recommended amount of moderate physical activity.[14] Substantial evidence has continued to show the steep decline in physical activity during adolescence (Table 4).[27-31, 34, 41, 42] The reason for the steep decline is unclear. Aaron and colleagues illustrated that the decline of physical activity is related to the amount of activities adolescents are engaging in rather than the time spent on the activity itself.[31] The decline in physical activity has been reported to start around age 11-13 years and continue through young adulthood. [27-30, 34, 41, 42] Longitudinal studies have demonstrated this pattern by following participants over as little as two years and up to twenty years.[28, 41] Kemper et al.

examined physical activity patterns in a sample of 186 participants beginning in adolescence through young adulthood.[41] Physical activity was measured at eight time points over a ten year study period. Energy expenditure (EE) during physical activity decreased by 1500 METS over the ten year study. One metabolic equivalent (MET) is defined as "the amount of energy expended during one minute of rest."[59] EE was assessed eight times throughout the study period via a physical activity questionnaire. Participants were asked about the following: participation in organized and unorganized sports, active transportation (i.e. walking, cycling) and other activities done at work, home and/or school which might result in a significant expenditure of calories.

Table 4: Main findings of the literature examining the initial age of physical activity decline

Author	Subject's Age (years)	Sample Size	Duration of follow-up (# of assessments)	Age of Noticeable Decline in P.A. (years)
Telama et al.[27]	9	1687	9 years (4)	12
Kemper et al.[41]	13	300	20 years (9)	13
Kettaneh et al.[28]	13	436	2 years (2)	13
Kimm et al.[34]	9 and 10	2322	10 years (10)	11-12
Aaron et al.[31]	12-15	782	4 years (4)	13

2.1.4.1 Gender differences in physical activity

Numerous studies have found that gender differences exist regarding physical activity.[27-32] Overall, adolescent males are more physically active than females at all age levels.[30] A study conducted in Finland using 12-27 year old participants found that 55% of males and only 20% of females participated in moderate and/or vigorous activity.[27] The type of physical activity that declines differs between males and females. A separate study by Kettaneh et al. found that females specifically declined in the amount of moderate activity per week while males declined in ambulatory (i.e. walking measured via a pedometer) activity per week.[28] Energy expenditure through physical activity has been reported to decline by 42% in males and 17% in females from age 13 years to age 27 years.[29] The largest percentage of the decline occurred between the ages of 13-16 years.

2.1.4.2 Racial differences in physical activity

Racial disparities in regards to physical activity have been reported. African Americans and Hispanics report the lowest levels of physical activity.[14] One particular study found that at baseline, physical activity levels were comparable between nine and ten year-old black and white females; however, significant differences by race appeared as the sample grew older .[35] Ten years after the study began, 32% of white females maintained an active physical activity level while only 11% of the black females remained active. On the other hand, 58% of the black females reported an inactive lifestyle while only 28% of the white females reported being inactive. The steepest decline in physical activity level in both races occurred between the ages of 13-16 years. Overall, habitual activity declined 83% over the ten year time, while daily physical activity declined by 35%.[34]

Physical activity not only declines but the type of physical activity children engage in changes. In 2003, the CDC reported that only 38.5% of children, including all races, between the ages of 9-13 years participated in organized sports.[36] By contrast, 77.4% were reported to have participated in free-time physical activity. (Free-time physical activity is defined as "self-reported engagement during the days preceding the survey in a free-time physical activity."[35])

This report also showed that children classified as Non-Hispanic black and Hispanic were less likely than non-Hispanic white children to participate in organized sports as well.

2.2 OBESITY IN ADOLESCENCE

2.2.1 Definition of obesity

The underlying cause of obesity stems from a person having a higher energy intake compared to the amount of energy they are expending. A reference scale used as a screening tool for obesity is body mass index (BMI). BMI is calculated using the following formula:

$$BMI = weight\ (kg)\ /\ height\ (m^2)$$

Adults with a BMI of greater than or equal to 30 kg/m^2 are considered to be obese.[60] The Centers for Disease Control and Prevention (CDC) use a different terminology for the pediatric population due to the sensitivity of classifying a child as obese. Once BMI is calculated using the same equation as adults, BMI is plotted on the appropriate CDC growth chart for age and gender. Children between the 85^{th} and 95^{th} percentile are classified as “at risk for overweight”. [61] Children with a BMI above the 95^{th} percentile are classified as “overweight”. [61]

2.2.2 Prevalence of obesity

There are many factors that contribute to gaining weight throughout childhood. These factors include social, behavioral, cultural, genetic, physiological and environmental aspects. The decline of physical activity has been negatively correlated to the increasing rate of obesity.

Within the past decade, the prevalence of obesity has increased dramatically in the United States causing an immediate concern for health professionals.[15] The prevalence of adult obesity increased from 22.9% in 1994 to 30.5% in 2000.[62] The National Health and Nutrition Examination Survey (NHANES) also reported that 64.5% of Americans were either overweight or obese in 2000 compared to 55.9% in 1994. By 2004, 65.7% of adults were found to be overweight or obese.[37] This trend of increasing prevalence of obesity was consistent among both men and women, across all ethnic groups, and across Americans of differing socioeconomic status. Some groups, however, are disproportionately affected by obesity. Non-Hispanic Black women over the age of 40 years, for example, have a prevalence of obesity over 50% and a combined prevalence of those categorized as both obese and overweight of approximately 80%.[37]

Obesity is also becoming increasingly common among children. In 2002, the NHANES data reported that 15% of children, ages 6-19 years, were at risk for overweight, while 16% were overweight.[37] Obesity increased most rapidly among Mexican-Americans and non-Hispanic Black children. The prevalence of obesity is strongly influenced by socioeconomic status as well. Obesity is twice as common among lower income families compared with middle or upper income families.[15]

2.2.3 Consequences of obesity

The medical and psychosocial consequences of obesity are serious. In 2005, Dietz et al. reported that 60% of children/adolescents have at least one of the consequences associated with being overweight.[63] Children who are overweight have different growth patterns compared to non-overweight children.[64, 65] Overweight children initially grow taller and enter puberty at a younger age than non-overweight children, therefore tend to be smaller in stature as adults.[64] Cardiovascular risk factors such as hypertension and hyperlipidemia are associated with childhood obesity.[39] In addition overweight children are more likely to be diagnosed with abnormal glucose metabolism leading to impaired glucose tolerance and type 2 diabetes mellitus,[38] respiratory problems such as sleep apnea,[10] orthopedic problems including Blount's disease, femoral bowing, and the hip abnormality known as "slipped capital femoral epiphysis".[40] Moreover, there are psychosocial consequences associated with overweight children.[3, 11] Overweight children may not be as popular among their peers as non-overweight children[12] and can be subjected to being teased or ridiculed about their weight issues.[13]

A recent study by Wardle and colleagues concluded that weight status established at age 11 years is a strong marker of persistent overweight status.[66] Most disturbingly is that 79% of adolescents who are overweight go on to be overweight or obese as adults.[43] The adult weight status may be dependent on the severity of obesity during adolescents and the age of onset. Overweight adolescents grow up to become significantly more obese as adults, compared to adults who were not overweight during their adolescence.[43]

2.2.4 Patterns of body weight changes in adolescence

Adolescents naturally gain weight as they mature.[41, 67] Gradual increases in weight occur among both sexes, independent of other variables such as diet or exercise.[41] During the adolescent growth and development period, females gain an average of 18.2 kg, while males can gain as much as 20.5kg.[68] This increase in weight occurs naturally between ages 10-14 among females and 12-16 years for males. During adolescence, the largest gains in height occur. Females grow on average two centimeters during the adolescent growth spurt, while males grow an average of five centimeters. Weight gain during puberty depends on weight percentile prior to puberty. A ten-year-old child with a BMI at the 95th percentile, for example, would be expected to gain more weight during puberty than a ten-year-old child with a BMI at the 50th percentile. Body composition also differs between males and females. Thirteen-year-old females have a higher percentage of body fat than 13-year-old males. Unlike females, males experience a decline in body fat percentage between the ages of 13 and 15.[28]

2.3 ADOLESCENCE PHYSICAL ACTIVITY LEVELS IN RELATION TO BMI

Between the age of 11 and 14, the BMI of adolescents increases by roughly 3.59 units.[69] This increase is partly mediated by levels of physical activity.[69, 70] BMI is more likely to increase rapidly among children who consume many unhealthy snacks per day, skipping breakfast daily, come from poor families, and watch a large amount of television. [69, 70] Factors contributing to weight gain differ between males and females.[70] One study has shown that adolescent females with the highest BMI increases reported a higher caloric intake, more sedentary time and had fewer hours of overall physical activity.[70] Males had similar trends; however, reported spending more time watching television and playing video games and less time being physically active.[70]

Overall, the literature has reported, fluctuations in body composition with in as little as one year as physical activity declines.[28, 35, 58, 69-72] Although two of these studies used a younger aged sample (3.9-5.6 years)[58, 71] and thus do not coincide with the current study under investigation, the remaining four studies used adolescent samples. These studies have been inconsistent in finding an inverse relationship between physical activity and body composition. Berkey et al. followed a sample of 11,877 adolescents aged 10-15 years for one year assessing their dietary intake, physical activity, sedentary time and height/weight.[70, 72] The study measured the following activity variables: in-school physical activity, out-of-school physical activity, and television/computer/videogame time (unrelated to school homework/projects). BMI values were calculated based on self-reported heights and weights measured by the participant's parent/guardian. Overall, the results indicated that large increases in BMI were found among girls who reported high caloric intakes, less physical activity and more sedentary time and for boys who reported more sedentary time.

Similar results were found for Kimm et al., using a baseline sample of roughly 2,300 nine and ten year old females, followed thru age 18-19 years.[35] At study year one, three, five, seven, eight and ten, the following measurements were obtained: physical activity (via Habitual Activity Questionnaire), dietary intake (via three-day food dairy), and body composition (height, weight, and skinfolds). Prior to analysis, the subjects were categorized into one of three physical activity categories, inactive, moderately activity or active. The results indicated that over ten years, for every 10 MET decline of physical activity, both BMI value and skinfold thickness increased.

Studies on the other hand, have found that weight status and physical activity may not be inversely related during adolescence.[28, 69] One in particular, Kettaneh et al., found that females in the highest level of physical activity at baseline, predicted the highest gain in all adiposity indicators (percent body fat and skinfolds data) at baseline.[28] Adolescents for this study were non-obese at baseline and were assessed at baseline and one follow-up, two years later, for both height/weight and physical activity (via the MAQ). On the other hand, Elgar et al., followed a similar aged sample as the current study under discussion for four years, and found no association of physical activity in the increase or decrease of BMI.

Table 5: Main findings of the literature examining body composition in relation to physical activity

Author	Subject's Age (years)	Body Composition Measure (adiposity indicators)	Main Findings
Kettaneh et al.[28]	8-17	Tanita bioimpedance analyzer, skinfolds, waist circumference (wc), BMI	Females in the highest level of PA at baseline, predicted the highest gain at follow-up in all adiposity indicators.
Janz et al.[58]	5-8	Dual energy x-ray absorptiometry (DXA), BMI	Children with high levels of vigorous activity and low levels of sedentary behavior were less likely to gain weight over the study time period.
Moore et al.[71]	4-11	Height, weight, skinfolds	Children with the highest activity level had significantly lower BMI and skinfolds compared to those with lower activity levels.
Berkey et al.[70, 72]	10-15	BMI, percentile BMI	Increasing PA over one year was found to decrease BMI in females and overweight males.
Kimm et al.[35]	9-19	BMI, skinfolds	Each decline of 10 METS in PA was associated with an increase in BMI value.
Elgar et al.[69]	11-14	Height, weight, BMI	Sedentary time predicted the change in BMI rather than physical activity.

2.4 PREVENTION OF OBESITY IN ADOLESCENCE

Obesity prevention studies exist in a variety of settings including: community, school and clinical.[73-76] The following section will discuss and summarize each intervention strategy.

2.4.1 Community-based interventions

Strategies for community based interventions have included education and counseling by nutritionist or physical trainers,[74] community physical activity competitions,[75] after school programs,[76] summer camps,[76] or offering free fitness club memberships.[74] These strategies have been conducted as both family[73, 74] and individual[75, 76] interventions.

Nader et al. was successful in implementing nutrition changes among families of 5th and 6th grade children by teaching both nutrition, physical activity and behavioral lessons along with exercise sessions; however, the intervention was unable to increase physical activity.[73] Kelder et al. however found that by challenging 6th grade children to increase their exercise outside of school in a community competition, physical activity was increased.[75] The same children were targeted again in 10th grade, where a second intervention was implemented using peer-led, individual counseling to increase knowledge and awareness of physical activity and nutrition. The treatment group was found to have significantly higher levels of physical activity compared to the control group.

Limitations of these interventions have included attendance, cost, and administrative issues around implementation of the protocol. The attendance issue is very evident when working with the entire family.[73] There often can be too many scheduling conflicts and the intervention often cannot be conducted in the manner intended.[76] Another concern is the structure of the intervention and whether it is properly implemented by the research staff.[76] With many of these studies the cost of the intervention is another major issue. It is hard to relate these studies in "real world" settings where cost is of concern to a family. Table 7 examines the community interventions that have been done to prevent obesity in the adolescent population.

Table 6: Main findings of the literature examining community interventions to prevent obesity in adolescents

Author	Sample	Intervention	Behaviors Targeted (Diet/Exercise)	Results
Nader et al.[73]	Families of 5th-6th grade children	Initial 1x/wk for 3 mo intensive sessions. Fup 1x/mo for 9 mo. Lesson & exercise sessions & family behavior session	Increase PA Decrease high salt/ fat foods	Eating habits were improved Non-Hispanic white group decreased total fat and sodium intake No differences found among PA level.
Baranowski et al.[74]	Families of 5th-7th grade children	1 educational & 2 fitness sessions/wk for 14 wks	Promoting PA	No significant results. Participation was low (20%)
Kelder et al.[75]	Sixth grade students (fup through 10th grade)	4 wk competition outside of school 10 educational lessons when students were in 10th grade.	Community competition to increase PA. Promote healthy regular PA.	PA (h/wk) was higher in the intervention grp for study period.
Pate et al.[76]	Fifth grade students	After-school and summer PA program.	Increase PA among youth	No significant effects on PA

2.4.2 School-based interventions

Another strategy to prevent adolescents from becoming overweight is to intervene in schools. Studies have attempted to increase nutrition and physical activity education in the classroom[77, 78] and improve physical education classes.[79-81] Additional studies have focused on decreasing sedentary time by cutting back on television viewing.[82] Compared to the community based obesity prevention initiatives, the school based approaches appear to show more promising results. Only one out of the seven interventions was unsuccessful in decreasing BMI.[80] This study by Neumark-Sztainer et al. did maintain BMI and improve overall behaviors and attitudes toward healthier lifestyle practices among the intervention cohort.

Positive results were found when changes to the existing school curricula were made in regards to nutrition and physical activity education.[77, 78, 83] Interventions in this area were able to successfully promote healthy eating and exercise habits which in return decreased adiposity. School based studies that focused on the physical education classes alone were able to impact overall health behaviors by changing attitudes and behaviors regarding physical activity and sedentary time.[79-82] Table 8 examines these school-based interventions.

Table 7: Main findings of the literature examining school-based interventions to prevent obesity in adolescents

Author	Sample	Intervention	Behaviors Targeted (Diet/Exercise)	Results
Gortmaker et al.[77]	6th-8th grade students	Educational sessions were added to existing curricula.	↓ TV viewing, ↓ high fat foods, ↑ intake of fruits and vegetables, ↑ PA	Females in tx grp had decreased prevalence of obesity. Reduced TV viewing in body genders in tx group. Increased fruit/veg intake.
Kain et al.[78]	1st-8th grade students	Nutrition education; 90min/wk of PA; behavioral PA program, active recess	Promote healthy eating and exercise behaviors.	Increased physical fitness in both genders. Decreased adiposity in males.
Sahota et al.[83]	4th-5th grade students	To influence dietary and PA behaviors in each individual school based on its own needs using "school action plans".	Promote healthy eating and exercise behaviors.	Successful in implementing "school action plans". Successfully made changes in risk factors for obesity at the school level.
McKenzie et al.[79]	3rd grade students followed for 2.5 years	Intervened in PE class by developing sessions, carrying out curricula and fup consultations with PE teachers.	Increasing PA	Moderate and vigorous levels of physical activity were increased in the schools with the CATCH PE classes.
Neumark-Sztainer et al.[80]	Females in 9th-12th grade	Females only PE program. 4d/wk of PE class	Increase PA and improve eating habits.	No change in BMI among tx group. Changes in behavior and attitudes of making healthy changes did occur in tx group.
Robinson et al.[82]	3rd-4th grade students	18 lessons over 6 mo on reducing sedentary behaviors.	To decrease sedentary time.	Tx grp had lower amt of time in sedentary behaviors along with decreased BMI.
Flores[76]	7th grade students (91%AA and Hispanic)	Aerobic dance class 3x/wk for 12 weeks	Increase aerobic fitness, decrease body weight, and promote more positive attitude towards P.A.	Students in tx group had decreased BMI and decreased resting HR compared to control.

Success of the school based studies may be attributed to children viewing school as a place to learn. Attendance and staffing issues are not typical problems that occur with school-based interventions. School based interventions have shown promising results with increasing children's awareness of physical activity and recognizing the importance of this issue regarding their health and well-being. To combat the prevalence of obesity these interventions provide evidence that school systems need to be incorporated into the solution. Physical education and health classes, the school lunch program, and the selection of snack and beverage machines also should be targeted. Each school system should explore their current system in place for teaching children healthy lifestyle behaviors and intervene where needed. Potential issues that influence physical activity behaviors include environmental, psychological, social and demographic factors.[84] Among these factors include the determinants of self-efficacy, knowledge, attitudes, peer influences, and safety. These can potentially be used as tools to develop interventions to influence physical activity behaviors.[84]

The prevalence of obesity may be reduced in adolescence starting with the school systems. Research has indicated a variety of strategies that have encouraging results. In the future school systems should become familiar with such strategies and incorporate these ideas into their own system in the hopes to control the onset and incidence of childhood obesity nationwide.

2.4.3 Clinic-based interventions to treat and prevent obesity

Treating obesity in a pediatric clinical setting is relatively new. A recommendation for the treatment of pediatric obesity has been identified by the American Academy of Pediatrics (AAP) for primary care physicians.[85] The AAP suggests that physicians should focus on the prevention of weight gain for children who are in the "at risk for overweight" category (defined as a BMI between the 85th and 95th percentile by the CDC) and under seven years of age. [61] Children in the BMI category of "overweight" (defined as above the 95th percentile for BMI) and who have at least one obesity related co-morbidity, the AAP recommends focusing on initiating weight loss. For children older than 7 years that fall into either the "at risk for overweight" or "overweight" category, weight loss is recommended.

Following the AAP guidelines in a primary care setting has been difficult for physicians.[86] Presently, obesity is not a reimbursable disorder for most insurance companies. Due to this issue, physicians typically see the overweight adults and children after they have developed a co-morbidity. Financial reimbursement is not the only barrier that physicians face. A recent survey of pediatricians found that the main barriers for treating patients include; reimbursement by insurance companies, lack of a dietitian on staff, and lack of educational materials for families concerning weight loss guidelines.[87] Interestingly, only 12% of these pediatricians reported high levels of self-efficacy in treating their patients for obesity. Even with these reported barriers, counseling obese patients in a clinic has increased over the years. In 1995 only 4.3% of physician appointments included treatment and/or management of obesity-related counseling. In 2001 the number went to 19.0%, and 15.4% in 2002.[88]

To date, there have been two interventions conducted in a primary care setting for the treatment and prevention of pediatric obesity.[89, 90] Information regarding the intensity and results of each intervention are included in Table 9. Both programs were conducted as a web based intervention targeting an adolescent population. Saelens et al. used both a web based program along with phone calls to provide nutrition and exercise information, as well as feedback on individual health habits and weight loss.[89] Although this intervention was not able to accomplish weight loss in the treatment group, subjects were able to maintain their BMI for one year. In a pediatric population, stopping the progressive weight gain is often considered a success.

White et al. incorporated the entire family into a web-based program.[90] This intervention provided weekly materials focused on weight loss along with weekly individual email communications for the treatment group regarding food logs. This intervention was not only able to decrease the adolescents BMI, but decreased the parents BMI as well.

Table 8: Summary of web-based interventions to prevent and treat obesity

Author	Subjects	Program Intensity	Results
Saelens et al.[89]	12-16 y	- Web-based intervention - Computer program provided initial assessment on eating and exercise habits - Computer program generated individual plans to improved health habits - 8 weekly phone calls; 3 biweekly phone calls provided feedback to subjects in regards to their health habits and weight changes - Subjects were encouraged to self-monitor diet and exercise - Exercise goals 5x/week for 60 minutes (subjects were increased gradually to reach this goal) - Control group: non-tailored physician counseling session	- tx group maintained BMI for 1 year - control group increased BMI 1.4 units
White, M.A. et al.[90]	11-15 y	- Family based internet intervention program - Weekly materials focused on weight loss were provided on the web - Weekly email communication by subjects to dietitian regarding food logging - Recommended to exercise regularly - Control group: provided separate website with nutritional lessons	- tx group decreased 0.24 kg/m2 - control group increased 0.71 kg/m2 Parents: - tx grp decreased 0.90 kg/m2 - control grp decreased 0.12 kg/m2

To assist primary care physicians, local pediatricians, and family medicine practices, outpatient weight management programs have been implemented. Such weight management programs in pediatric hospitals were put in place with the objective of assisting children in reaching healthy weight goals and to prevent further weight gain. Refer to Table 10 for a list of outpatient clinical interventions and specifications of each program. Savoye et al. and Sothern et al. show promising results in decreasing BMI in an adolescent population by implementing a year long intervention including both nutrition and exercise education.[91, 92] Weekly educational sessions were held in a group setting to promote healthy behaviors. This time was also used to weigh the participants as well as to monitor their diet restrictions.

Nemet et al. intervened with children and adolescents, 6 to 16 years of age, for a three month time period.[93] Using both weekly individual and group sessions a decrease in both BMI and percent body fat in the treatment group was observed, concluding that short term interventions for weight loss are beneficial for treating obesity. Table 10 summarizes existing intervention programs in outpatient clinics.

Table 9: Summary of outpatient clinical interventions to treat obesity

Author	Subjects	Program Intensity	Results
Savoye, M. et al.[92]	11-16 y	- 1 year intervention with weekly sessions; maintenance followed 1 year with monthly support group sessions - Subjects attended weekly group sessions (two 30 min exercise session along with one nutrition or behavior modification class - Two diet options for subject to choose individually: structured meal plan or education to make better food choices - Subjects encouraged to exercise 3d/week at home and decreased sedentary behavior	↓ BMI z-score
Sothern, M.S. et al.[91]	13-17 y	- Weekly 2 hour group sessions for 1 year - Sessions included: nutrition and physical activity education along with group exercise - Individualized weekly exercise prescriptions	↓ BMI ~ 4.1 units (1 year fup)
Nemet, D. et al.[93]	6-16 y	- Individual sessions with dietitian 6 times over 3 months - Group exercise 2x/week and home exercise 1x/week - 4 group sessions within 3 month time period - Control group: met with dietitian once and instructed to exercise 3x/week	↓ BMI & body fat % (tx grp) no change in control group

The last approach to explore in a pediatric population uses a more intensive program by institutionalizing subjects in a hospital setting for a 10 month time period.[94] Please refer to Table 11 for program specifications. Overall, this intervention placed 27 subjects on a restricted diet and required them to exercise twice a week (supervised). The intervention was able to decrease BMI significantly for males and females, 8.1 and 6.3 kg/m^2, respectively. Unfortunately a program such as this is, most likely, not generalizable to a community for the treatment of obesity.

Table 10: Summary of inpatient clinical interventions to treat obesity

Author	Subjects	Program Intensity	Results
Lazzer, S. et al.[94]	12-16y	- 10 months, 5d/week, inpatient care at hospital - Restricted diet (4 meals/day) - 1x/week 2hr nutrition lesson - 2x/week 40 minutes exercise session	decreased BMI in both genders -males ↓ 8.1 kg/m2 -females ↓ 6.3 kg/m2

Outpatient programs are relatively new and data on outcomes does not yet exist for programs instituted in community hospitals. Table 12 (in the appendix) provides a list of weight management programs established in communities. If a local weight management center for children does not exist in a community standards of care are in place for a clinical setting. These recommendations include conventional treatment such as increasing exercise, decreasing sedentary time and implementing healthier eating patterns. [95] Healthy eating patterns include: limiting food portions, eliminating caloric beverages, and increasing fiber intake by consuming more fruits/vegetables. There are also guidelines appropriate for more severe or aggressive treatment with the patients that are >/= to 120% above ideal body weight. These aggressive treatments include: caloric diets of <800 calories, medications, and in some cases bariatric surgery. [95]

The treatment of childhood obesity may not be feasible for a clinical setting alone. The prevalence of obesity has progressively increased from year to year. Emphasizing more of a focus on environmental issues of obesity may be a more efficient strategy to stop this disease. Physicians have reported that the largest environmental barriers to treating pediatric obesity include: the school cafeteria and physical education environment, fast food chains, and caloric beverages. [87] These environmental barriers along with the physician's clinical treatment barriers warrant further investigation.

2.5 SUMMARY OF LITERATURE REVIEW

Based on this literature review, a relationship does exist between physical activity and weight. Research has also shown that variables including; number of snacks per day, irregular meal patterns, sedentary time and family socioeconomic status impact weight.[69, 70] A small number of studies have also shown that increased adiposity may be inversely related to changes in overall levels of physical activity, independent of gender.[28, 58, 70-72] Others have shown that children with the highest level of physical activity had significantly lower BMI values compared to children in the low to moderate ranges of physical activity.[71] Research has also shown that physical activity patterns are not stable overtime.[32, 41]

With the increasing prevalence of obesity among adolescence,[37] and the well known impact of this weight in regards to risk factors for various chronic diseases that start in adolescence,[10, 38-40] research needs to investigate clear mechanisms that have the potential to stop the progression of abnormal weight gain throughout adolescence. Research has found significant evidence that physical activity declines during adolescence. [27-30, 34, 41, 42] Knowing how changes in physical activity impact weight status over time may indicate that maintenance of physical activity is needed to promote weight management during adolescence. Thus adolescences may be a period in which implementation of physical activity interventions can impact health and well-being of these adolescents both now and in the future.

3.0 METHODS

3.1 INTRODUCTION

The purpose of this study was to examine the relation of physical activity on weight status in adolescents over a four year time period. This section is composed of the following sections: (3.2) Adolescent Injury Control Study, (3.3) Data Collection, and (3.4) Statistical Analysis.

3.2 ADOLESCENT INJURY CONTROL STUDY (AICS)

3.2.1 Overview of AICS

Participants for this longitudinal study were from the Adolescent Injury Control Study (AICS), a 4 year National Institutes of Health funded study. AICS examined the contribution of sport and recreational physical activity to all-cause injury incidence in adolescents. The main objectives of this study included 1) determining the incidence of physician-treated injuries in addition to the risk factors associated with the injuries and 2) assessing injury morbidity and mortality related to sports and recreational activities in a cohort of adolescents.

3.2.2 Participants

The AICS includes 7th, 8th and 9th grade students recruited from a local suburban school district in Pittsburgh, PA during August of 1989. Once students and their parents signed an informed consent form, approved by the University of Pittsburgh Institutional Review Board, they were entered into the study. Each of the 1245 participants, aged 11-16 years at baseline were followed for a four year time period. The original cohort consisted of males (n=643) and females (n=602). The majority of the participants were Caucasian (73%) and African American (24%) while 3% were Hispanic or Asian-American.

For the present analysis, students were excluded if they did not complete the physical activity questionnaire at baseline (n=70) and who reported more than 168 hrs/wk of physical activity (n=1). Also, students who were greater than 16 years of age at baseline (n=40) were excluded due to the inability to categorize their BMI using the standard pediatric BMI percentile categories from the CDC after the age of 18. Due to the low number of Hispanic (n= 7) and Asian (n= 8) students as well as students reporting "other" race/ethnic group (n=21), only Caucasian and African Americans were included in the present analysis. Because of the known racial/ethnic differences in physical activity patterns and the prevalence of obesity[14] , it was not possible to combine these students (Hispanic, Asian, Other Race/Ethnicity) into a single minority group. The remaining 1098 adolescents were used to test our main hypothesis.

3.3 DATA COLLECTION

3.3.1 Physical activity questionnaire

During the spring term of each school year (1990, 1991, 1992, and 1993), trained research staff administered the Modifiable Activity Questionnaire for Adolescents (MAQ), see Appendix A, during physical education classes.[96] The MAQ has been found to be both reproducible and valid in measuring physical activity in an adolescent population.[50] This questionnaire examined both recreational and leisure time activities. In order for a student to report an activity, they had to participate in the activity a minimum of ten times over the past year. Each student was provided a menu of 26 activities (i.e. aerobics, band/drill team, basketball, etc) to choose from along with blank spaces to add additional activities not listed. The frequency and duration of each activity listed was also recorded. This questionnaire estimates the total hours per week (hrs/wk) of overall leisure time activity in the past year. To calculate leisure-time physical activity, hrs/wk of each specific activity was first computed using the following equation[50]:

$$\text{Hrs/wk of activity} = \frac{(\#\ \text{mo/yr}) \times (4.3\ \text{wks/mo}) \times (\#\ \text{days/wk}) \times (\#\text{min/day})}{(60\ \text{min/hr}) \times (52\ \text{wks/yr})}$$

The hrs/wk for each activity was then summed to estimate the total physical activity averaged over the past year. In addition, each activity was classified into two groups, vigorous or moderate-light physical activity based on intensity. These categorizations were based on the metabolic (MET) value for each activity.[97] The hrs/wk for all activities classified as vigorous (>= 6 METS) were added to yield the total hrs/wk of vigorous PA. The hrs/wk for all activities classified as moderate/light (< 6 METS) were added to yield the total hrs/wk of moderate/light PA. In addition, each activity was classified as a team or individual activity. The hrs/wk for all activities classified as a team activity was added to yield the total hrs/wk spent participating in team activities. The hrs/wk for all activities classified as individual activity was added to yield the total hrs/wk spent participating in individual activities.

3.3.2 Body Composition

Height and weight was measured by research assistants from the AICS. A balance scale was used to measure weight and a wall mounted measuring tape was used to measure height. Date of birth, date of assessment, height, weight and gender, were entered into Epi Info (a computer based program provided by the Centers for Disease Control and Prevention) to calculate each participant's body mass index (BMI) and BMI percentile.[98] Each participant was categorized for weight status, at each year, as healthy weight, at risk for overweight or overweight, using the BMI percentile according to the CDC guidelines. The CDC defines children below the 85^{th} percentile in terms of BMI for age and gender as "healthy weight", between the 85^{th} and 95^{th} percentile as "at risk for overweight" and above the 95^{th} percentile as "overweight".[61]

3.3.3 Sociodemographic Data

Sociodemographic information for this analysis included: gender, race, and social economic status. Socioeconomic status (SES) was determined according to the poverty level of the neighborhood where the child resided. Each neighborhood was classified as having a high (less than 10% below poverty level), middle (10-20% below poverty level) or low (greater than 20% below poverty level) SES.[31]

3.4 STATISTICAL ANALYSIS

The objective of this study was to investigate the relation of physical activity on weight status in adolescents over a 4-year period. Specifically, the study was designed to test the main hypothesis that a decrease in the level of physical activity over 4 years will increase the risk and the likelihood of becoming overweight.

In this study, the main outcome variable was weight status, and the main predictor variable was the level of physical activity. Weight status was measured each year and was analyzed in two ways: as a categorical variable with 3 levels (normal, at risk for becoming overweight, and overweight) and as a continuous variable measured in terms of the body mass index (BMI) and the BMI percentile. Hrs/wk of various types of physical activities (team, individual, vigorous, and low-moderate activities) were measured each year via a questionnaire. The distributions of BMI and physical activity were examined to determine if they were normally distributed. If needed, transformations were used to normalize data prior to fitting a model.

All continuous variables used in the models were described in terms of means, standard deviations, medians, and ranges, while all categorical variables were described in terms of proportions. Comparisons of physical activity across gender, race and SES groups were examined using the Wilcoxon test for non-parametric data. Comparisons of body composition measurements across gender, race and SES groups were examined using t-tests and one-way analyses of variance (ANOVA) tests for the normally distributed data (height, weight and BMI percentile) and the Wilcoxon test for non-parametric data (BMI). Comparisons of weight status across gender, race and SES groups were examined using the chi squared test for normally distributed data.

The relationship between changes in weight status and changes in physical activity level was measured by two different methods: the same-year analysis method predicted weight status from the physical activity level measured in the same year, and the lag-year analysis method predicted weight status from the physical activity level measured during the previous year. Because the relationship between weight status and physical activity could be affected by gender, race, and socioeconomic status, these factors were included as covariates in the models. In cases in which data concerning a subject's weight status or physical activity were missing, the method of multiple imputations was used to increase the power of the analyses.[99] The number of imputations used was five. The SAS procedure PROC MI (SAS Institute, Cary, NC) was used to perform this analysis, and the procedure PROC MIANALYZE was used to combine the results from the five imputations.

The generalized mixed model approach[100] was used to test the main hypothesis. The outcome variable (weight status), and the main predictor (physical activity) were modeled longitudinally. For the covariates, the baseline data were used in the models. The SAS version 9.1 procedure GLIMMIX was used to conduct this analysis.

When the outcome variable (weight status) was treated as a continuous variable (BMI or BMI percentile), the curve for describing changes in the mean weight status over time was modeled as a polynomial function of time and the amount of physical activity. When the outcome variable (weight status) was treated as a categorical variable with three levels, the log odds of weight status (rather than the mean weight status) was modeled.

The same-year analysis was based on the following model:

$$\begin{aligned} E(\text{Weight}_{ij}) = {} & \beta_{0i} + \beta_{11}\text{PA}_{ij} + \beta_{12}\text{PA}_{ij}^2 + \beta_{13}\text{PA}_{ij}^3 + \beta_{21}\text{Time}_{ij} + \beta_{22}\text{Time}_{ij}^2 + \beta_{23}\text{Time}_{ij}^3 \\ & + \beta_3\text{Gender}_i + \beta_4\text{Race}_i + \beta_5\text{SES}_{ij} + \beta_{61}\text{PA}_{ij} \times \text{Time}_{ij} + \beta_{62}\text{PA}_{ij} \times \text{Time}_{ij}^2 \\ & + \beta_{63}\text{PA}_{ij} \times \text{Time}_{ij}^3 + \beta_{64}\text{PA}_{ij}^2 \times \text{Time}_{ij} + \beta_{65}\text{PA}_{ij}^2 \times \text{Time}_{ij}^2 + \beta_{66}\text{PA}_{ij}^2 \times \text{Time}_{ij}^3 \\ & + \beta_{67}\text{PA}_{ij}^3 \times \text{Time}_{ij} + \beta_{68}\text{PA}_{ij}^3 \times \text{Time}_{ij}^2 + \beta_{69}\text{PA}_{ij}^3 \times \text{Time}_{ij}^3, \end{aligned}$$

where Weight, PA, and SES represent weight status, physical activity level, and socioeconomic status, respectively; subscript i indicates each individual and subscript j indicates each time point (year 1990, year 1991, year 1992, or year 1993). β_{0i} is the random intercept for individual variations.

The lag-year analysis was based on a model with a similar form:

$$\begin{aligned} E(\text{Weight}_{ij}) = {} & \beta_{0i} + \beta_{11}\text{PA}_{j-1} + \beta_{12}\text{PA}_{i,j-1}^2 + \beta_{13}\text{PA}_{i,j-1}^3 + \beta_{21}\text{Time}_{ij} + \beta_{22}\text{Time}_{ij}^2 + \beta_{23}\text{Time}_{ij}^3 \\ & + \beta_3\text{Gender}_i + \beta_4\text{Race}_i + \beta_5\text{SES}_{ij} + \beta_{61}\text{PA}_{i,j-1} \times \text{Time}_{ij} + \beta_{62}\text{PA}_{i,j-1} \times \text{Time}_{ij}^2 \\ & + \beta_{63}\text{PA}_{i,j-1} \times \text{Time}_{ij}^3 + \beta_{64}\text{PA}_{i,j-1}^2 \times \text{Time}_{ij} + \beta_{65}\text{PA}_{i,j-1}^2 \times \text{Time}_{ij}^2 \\ & + \beta_{66}\text{PA}_{i,j-1}^2 \times \text{Time}_{ij}^3 + \beta_{67}\text{PA}_{i,j-1}^3 \times \text{Time}_{ij} + \beta_{68}\text{PA}_{i,j-1}^3 \times \text{Time}_{ij}^2 \\ & + \beta_{69}\text{PA}_{i,j-1}^3 \times \text{Time}_{ij}^3, \end{aligned}$$

where Weight, PA, and SES represent weight status, physical activity level, and socioeconomic status, respectively; subscript i indicates each individual and subscript j-1 indicates each time point (year 1991, year 1992, or year 1993). β_{0i} is the random intercept for individual variations.

4.0 RESULTS

4.1 INTRODUCTION

The purpose of this study was to examine the relation of physical activity to weight status in adolescents over a four-year time period. This chapter is composed of the following sections: (4.2) Subject Demographics, (4.3) Relationship between Primary Variables and Co-Variables, (4.4) Results of Specific Aims, and (4.5) Summary of the Results.

4.2 BASELINE SUBJECT CHARACTERISTICS

Baseline demographics for the study sample are illustrated in Table 12. The sample includes 568 (51.73%) males and 530 (48.27%) females between the ages of 11-15 years with a mean age of 13.5 years (±0.99). The sample includes 76.59% Caucasian and 23.41% African American participants. Over half (53.37%) of the participants were classified as middle socioeconomic status (SES), 28.32% high SES and 18.31% low SES. The median hrs/wk of physical activity at baseline was 13.10 hours. The participants had a mean height of 64.27 inches with a mean weight of 125.91 pounds. Overall 16.11 % of the participants were categorized as "at risk for overweight" while 10.35 % were categorized as "overweight".

Table 11: Baseline subject demographics

Variable	Percent (%)	Mean (sd)	Median (range)
Gender			
Males	51.73	-	-
Females	48.27	-	-
Race			
Caucasian	76.59	-	-
African American	23.41	-	-
SES			
Low	18.31	-	-
Middle	53.37	-	-
High	28.32	-	-
Age (years)	-	13.5 (0.99)	-
Physical Activity (hrs/wk)	-	-	13.10 (0-166.68)
Height (inches)	-	64.27 (3.55)	-
Weight (pounds)	-	125.91 (29.77)	-
BMI (kg/m^2)	-	21.30 (4.19)	-
BMI percent (%)	-	62.54 (26.61)	-
Percent Overweight	10.35	-	-
Percent At Risk for Overweight	16.11	-	-

4.3 LONGITUDINAL CHANGES IN PHYSICAL ACTIVITY AND THE RELATIONSHIPS TO COVARIATES

Overall, a significant decrease in total, individual and vigorous physical activity was shown at each study year ($p<0.01$) (Table 13). Team and light-moderate physical activity significantly decreased from 1991-1993 ($p < 0.01$) Figure 1 illustrates the decline in total PA by gender. Total physical activity for both males and females declined over the four study years, 43% and 14%, respectively ($p < 0.01$).

Table 12: Median hours/week of physical activity (PA) for all subjects

Year	PA	T-PA	I-PA	V-PA	LM-PA
1990 (n = 1098)	13.10	3.97	5.21	6.94	2.98
1991 (n = 980)	12.74	4.40	4.15	6.95	3.31
1992 (n = 879)	10.66	3.72	2.81	4.37	2.98
1993 (n = 756)	9.28*	3.00^	1.73*	3.12*	1.98^

PA = Total PA; T-PA = Team PA; I-PA = Individual PA; V-PA = Vigorous PA; LM-PA = Light-Moderate PA
* $p < 0.01$ decline from 1990
^ $p < 0.01$ decline from 1991

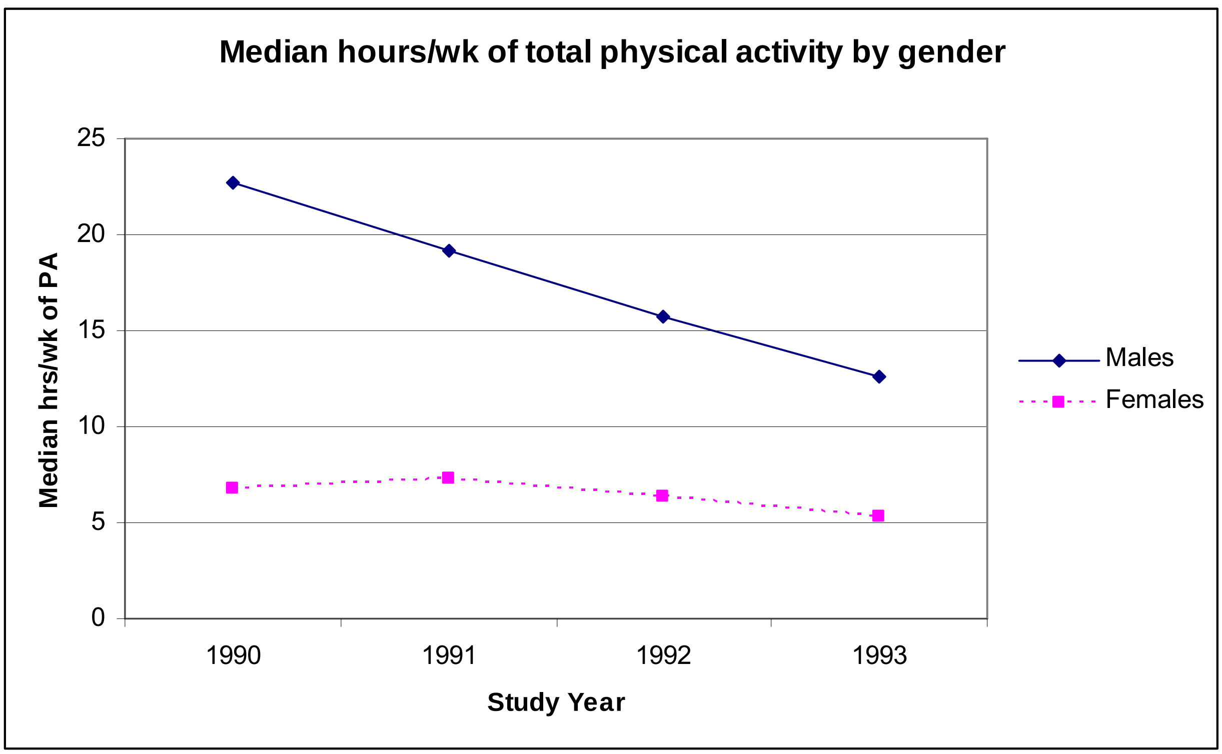

Figure 1: Median hours/wk of total physical activity by gender

For all years, males reported significantly ($p < 0.01$) more median hrs/wk of total PA, team PA, individual PA, vigorous PA and light-moderate PA compared to females (Table 14). Males also reported more median hrs/wk of team activities compared to individual activities, while females reported more hrs/wk of individual activities compared to team activities for all study years ($p < 0.01$). Males also reported more hrs/wk of vigorous activity compared to light-moderate activity ($p < 0.01$), this was not the case among the females. For study years 1990-1991, females reported more time in vigorous physical activity compared to light-moderate physical activity ($p < 0.01$), while in 1993 reported more time in light-moderate compared to vigorous ($p < 0.05$). No significant difference was found in year 1992.

Table 13: Median hours/week of physical activity (PA) by gender

Gender	Year	PA	T-PA	I-PA	V-PA	LM-PA
Male	1990 (n = 568)	22.66*	9.31*	7.61*	12.26*$^{+}$	4.63*
	1991 (n = 515)	19.18*	9.93*^	4.63*	11.74*$^{+}$	4.47*
	1992 (n = 460)	15.71*	8.98*^	3.31*	8.89*$^{+}$	3.97*
	1993 (n = 397)	12.61*	7.94*^	2.48*	7.11*$^{+}$	2.81*
Female	1990 (n = 530)	6.80	1.32^	3.72	3.15^{+}	1.90
	1991 (n = 465)	7.32	1.28^	3.76	3.30^{+}	2.15
	1992 (n = 419)	6.37	0.66^	2.35	1.57	1.74
	1993 (n = 359)	5.30	0.00^	1.41	0.50○	1.12

PA = Total PA; T-PA = Team PA; I-PA = Individual PA; V-PA = Vigorous PA; LM-PA = Light-Moderate PA
* $p < 0.01$ compared to females
^ $p < 0.01$ team compared to individual physical activity
$^{+}$ $p < 0.01$ vigorous compared to light-moderate physical activity
○ $p < 0.05$ vigorous compared to light-moderate physical activity

The amount of weekly physical activity was found to differ among racial groups (Table 15). Throughout all study years Caucasian adolescents reported a greater amount of median hrs/wk of total physical activity compared to African Americans, in 1990 (13.97 vs. 11.25; $p < 0.05$), 1991 (13.40 vs. 9.93; $p < 0.01$), 1992 (11.41 vs. 7.28; $p < 0.01$), and 1993 (9.92 vs. 6.28; $p < 0.01$). In study year 1992 only, Caucasian adolescents had significantly more median hrs/wk of team PA in comparison to African American adolescents ($p < 0.05$). Caucasian adolescents reported significantly more median hrs/wk of individual activity compared to African American adolescents for study years 1990 ($p < 0.05$) and 1991 and 1993 ($p < 0.01$). Both Caucasian and African American adolescents reported more time in vigorous activity compared to light-moderate activities ($p < 0.01$). In years 1992 and 1993, Caucasian adolescents reported significantly more vigorous activity compared to African American adolescents ($p < 0.01$, $p < 0.05$), respectively. Across all years, Caucasian adolescents reported significantly more light-moderate physical activity compared to African American adolescents ($p < 0.01$).

Table 14: Median hours/week of physical activity (PA) by race

Race	Year	PA	T-PA	I-PA	V-PA	LM-PA
Caucasian	1990 (n =841)	13.97*	3.97^	5.70*	6.61▪	3.47^{Δ}
	1991 (n =761)	13.40^{Δ}	4.34○	4.87^{Δ}	6.95▪	3.72^{Δ}
	1992 (n =693)	11.41^{Δ}	3.97 *	3.23^{Δ}	4.71^{Δ}▪	3.31^{Δ}
	1993 (n =624)	9.92^{Δ}	3.01	2.13^{Δ}	3.43*▪	2.48^{Δ}
African American	1990 (n =257)	11.25	4.13	4.18	7.93▪	1.49
	1991 (n =219)	9.93	4.46○	2.98	6.04▪	2.07
	1992 (n =186)	7.28	2.91^	0.99	2.98▪	0.29
	1993 (n =132)	6.28	2.98^	0.00	2.11▪	0.00

PA = Total PA; T-PA = Team PA; I-PA = Individual PA; V-PA = Vigorous PA; LM-PA = Light-Moderate PA
* $p < 0.05$ compared to African American
$^{\Delta}$ $p < 0.01$ compared to African American
^ $p < 0.01$ team compared to individual physical activity
○ $p < 0.05$ team compared to individual physical activity
▪ $p < 0.01$ vigorous compared to light-moderate physical activity

Relationships regarding SES level and the amount of physical activity per week were also found in this sample (Table 16). Although not all relationships were found to be significant, generally, as SES level increased, the amount of physical activity increased, with the lowest SES group reporting the least amount of physical activity. The adolescents categorized into the high SES group reported more median hrs/wk of total physical activity compared to those in the middle SES group in 1992 (12.02 vs. 10.59; $p \leq 0.01$) and 1993 (10.50 vs. 8.69; $p \leq 0.01$) and the low SES group in 1991 (14.18 vs. 9.92; $p \leq 0.01$), 1992 (12.02 vs. 7.20; $p \leq 0.01$), and 1993 (10.50 vs. 6.83; $p \leq 0.01$). Although the middle SES group reported higher total physical activity compared to the low SES group, only in year 1992 a significant difference was found (10.59 vs. 7.20; $p < 0.05$).

Although not significant, as SES group increased, so did the reported hrs/wk of team sports. Significant relationships were found however for time participating in individual activities. For study years 1991-1993, those adolescents classified in the high SES group were found to have significantly more median hrs/wk of individual activity compared to those in the middle SES group ($p < 0.05$) and low SES group ($p \leq 0.01$). Adolescents in the middle SES group were also found to have significantly more median hrs/wk of individual activities compared to those in the low SES group for study years 1992 and 1993 ($p \leq 0.01$).

Only a few significant differences were found regarding the intensity of physical activity data. Overall when adolescents in this sample were active, they tended to participate in vigorous activities rather than light-moderate activities ($p < 0.05$). For most study years (except 1990), as SES level increased, the amount of time reported participating in vigorous activities increased. For study years 1991 and 1992, the high SES group reported significantly more vigorous physical activity compared to low SES group ($p < 0.05$, $p \leq 0.01$) and middle SES group in 1992 ($p \leq 0.01$).

As for light-moderate physical activity, at all study years, adolescents in the high SES group reported more median hrs/wk compared to those in the low SES group ($p \leq 0.01$). Throughout all study years, the middle SES group reported significantly more light-moderate physical activity compared to the low SES group ($p < 0.05$).

Table 15: Median hours/week of physical activity (PA) by SES

SES	Year	PA	T-PA	I-PA	V-PA	LM-PA
Low SES	1990 (n =201)	12.57	3.47	5.20¤	8.35 e	1.89
	1991 (n =170)	9.92	4.13	2.98	5.30 e	2.48
	1992 (n =154)	7.20	2.98 Ж	1.08	2.98 e	1.65
	1993 (n =110)	6.83	3.10 Ж	0.00	1.76 e	0.62
Middle SES	1990 (n =586)	13.23	3.97	4.96¤	6.60 e	3.31+
	1991 (n =527)	12.98	4.63	4.14	6.60 e	3.47+
	1992 (n =455)	10.59+	3.47	2.48+	4.14 e	2.98+
	1993 (n =398)	8.69	2.98 Ж	1.49+	2.69 e	1.98+
High SES	1990 (n =311)	13.64	4.46	5.75¤	6.94 e	3.47*
	1991 (n =283)	14.18 *	4.47	5.95 Δ *	7.60 * e	3.72*
	1992 (n =270)	12.02 Δ *	4.30	3.81 Δ *	5.46 Δ * e	3.35*
	1993 (n =248)	10.50 Δ *	3.27	3.06 Δ *	4.51 e	2.48 *

PA = Total PA; T-PA = Team PA; I-PA = Individual PA; V-PA = Vigorous PA; LM-PA = Light-Moderate PA
* $p < 0.05$ High SES compared to Low SES
Δ $p < 0.05$ High SES compared to Middle SES
+ $p < 0.05$ Middle SES compared to Low SES
¤ $p < 0.05$ individual compared to team physical activity
Ж $p < 0.05$ team compared to individual physical activity
e $p < 0.05$ vigorous compared to light-moderate physical activity

4.4 LONGITUDINAL CHANGES IN BODY COMPOSITION VARIABLES AND THE RELATIONSHIPS TO COVARIATES

Overall, males in the sample increased in height by an average of 3.68 inches and gained an average of 33.36 pounds. Females, increased in height by an average of 1.02 inches and gained an average of 13.58 pounds. Throughout all four study years males were significantly taller and weighed significantly more than females ($p < 0.01$). Figures 2-3 illustrate mean heights and weights according to the adolescent's gender and age at baseline.

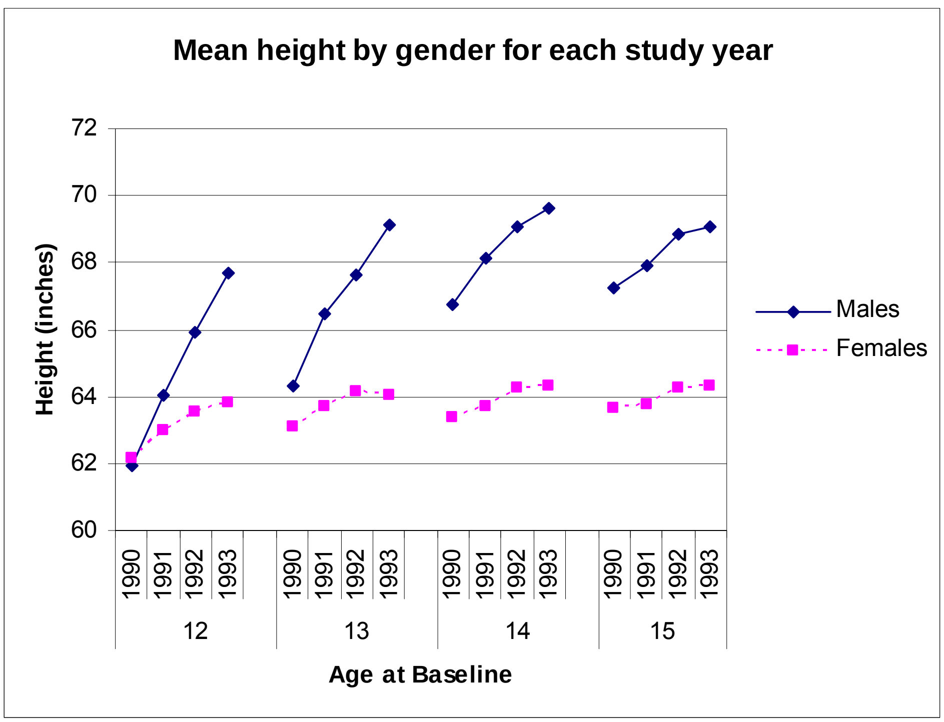

Figure 2: Mean height by gender for each study year by age at baseline

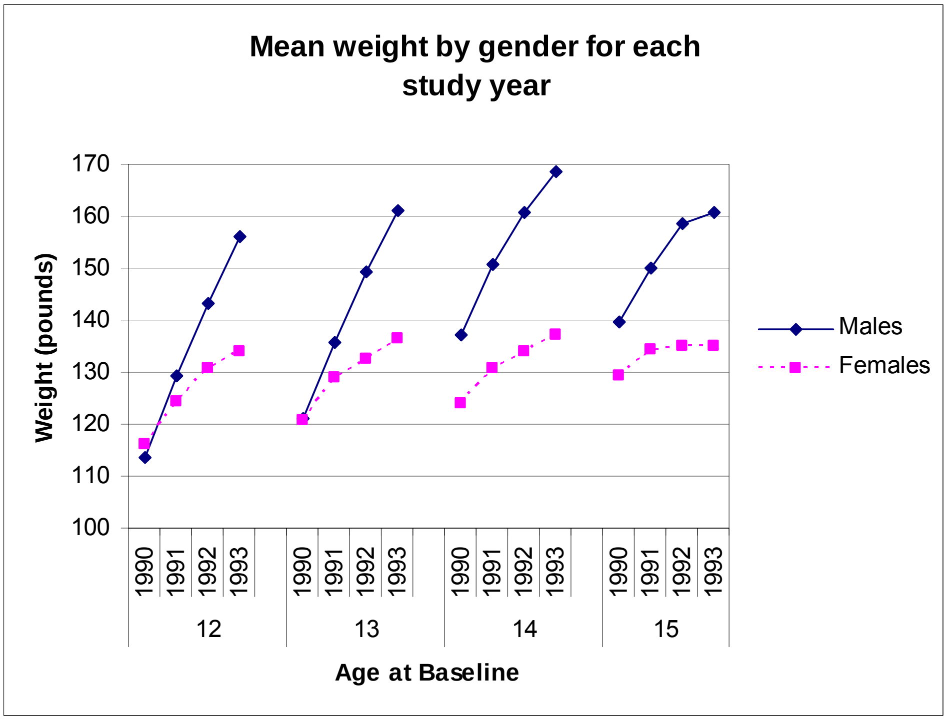

Figure 3: Mean weight by gender for each study year by age at baseline

Significant gender differences were also found regarding BMI and BMI percentile. At baseline, females had a significantly higher BMI value (20.77 vs. 20.13) ($p < 0.01$) and BMI percentile (64.19 vs. 60.98) ($p < 0.05$) than males. No significant difference regarding BMI for 1991 among males and females was shown (21.13 v. 21.60; $p = 0.17$). However, for study years 1992 (22.16 vs. 21.77; $p < 0.05$) and 1993 (22.70 vs. 22.14; $p < 0.01$), male BMI values were significantly higher than female BMI values. No significant differences were found regarding BMI percentile among males and females in 1991 (63.67 vs. 65.38; $p = 0.30$), 1992 (65.32 vs. 62.94; $p = 0.17$), and 1993 (65.05 vs. 62.51; $p=0.18$). Figure 4 and 5 illustrate changes in BMI and BMI percentile by the adolescent's gender and age at baseline.

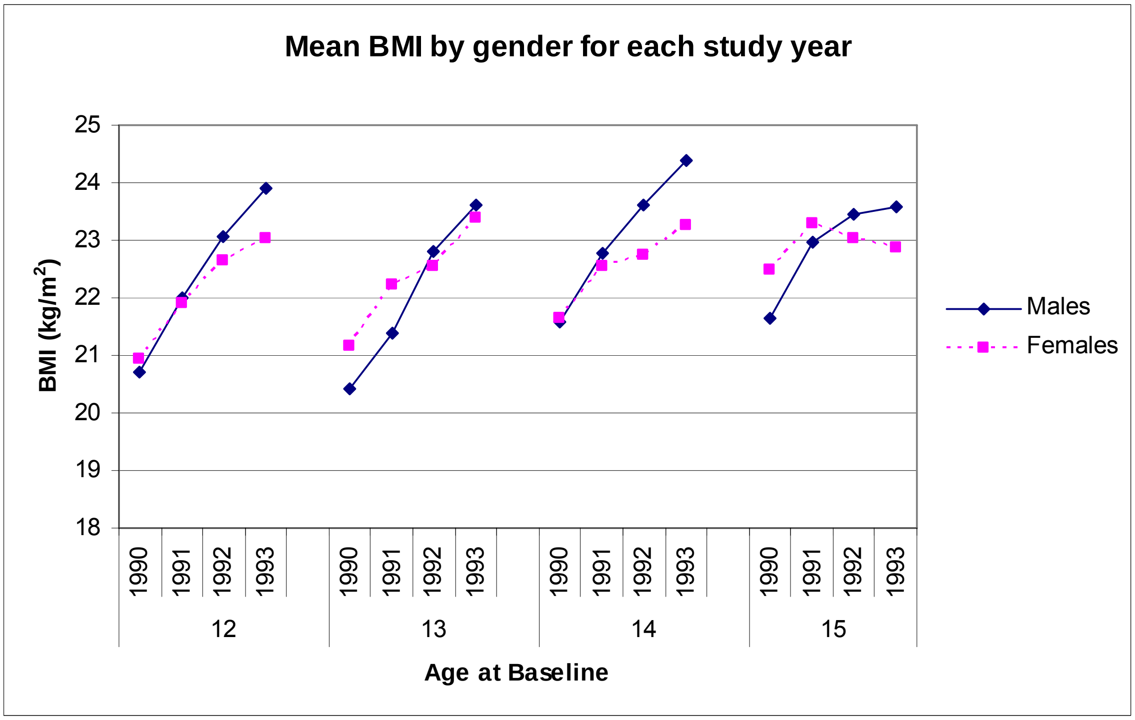

Figure 4: Mean BMI by gender for each study year by age at baseline

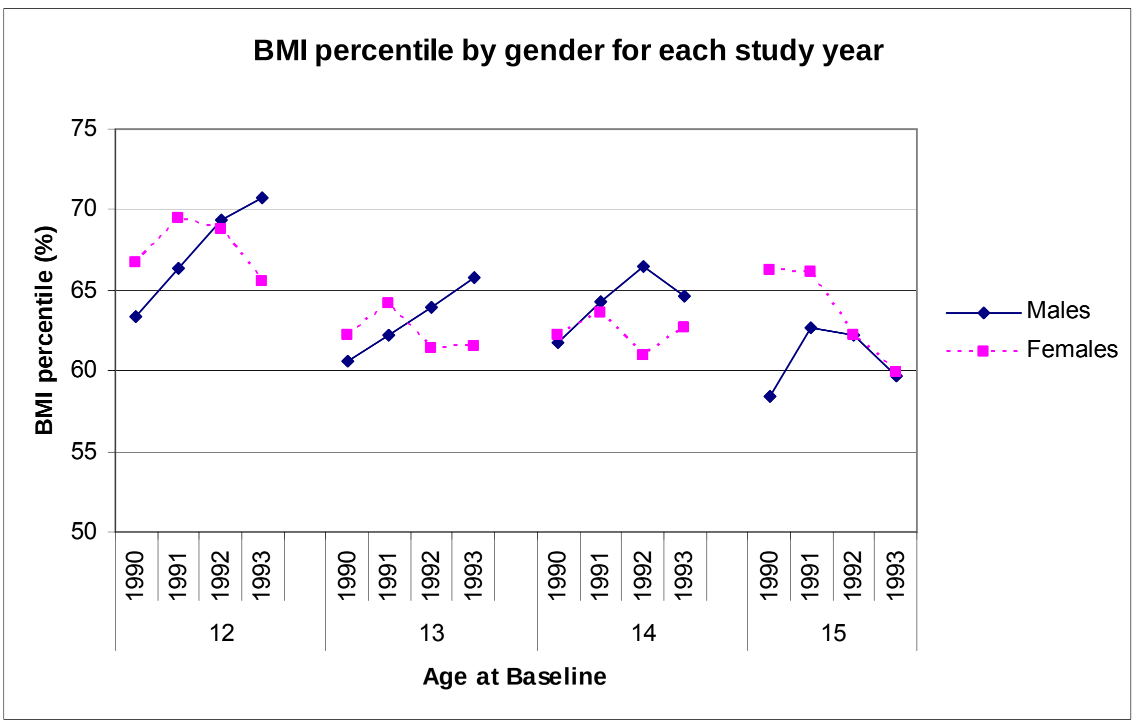

Figure 5: BMI percentile by gender for each study year by age at baseline

Racial differences were found throughout our sample of adolescents, regarding body composition measurements (Table 17). Throughout most study years, African American adolescents were taller than Caucasian adolescents; however, not significantly different. For all study years, African American adolescents weighed more than Caucasian adolescents ($p < 0.05$). African American adolescents had significantly ($p < 0.01$) higher BMI values compared to Caucasian adolescents in 1990 (21.14 vs. 20.26), 1991 (21.95 vs. 21.11), 1992 (22.55 vs. 21.71), and 1993 (23.02 vs. 22.27). African American adolescents also had significantly ($p < 0.05$) higher BMI percentiles compared to Caucasian adolescents in 1990 (66.50 vs. 61.32), 1991 (67.68 vs. 63.57), 1992 (67.53 vs. 63.24), and 1993 (68.52 vs. 62.83).

Table 16: Body composition measures categorized by race.

Race	Year	Height (in)	Weight (lbs)	BMI (kg/m^2)	BMI Percentile (%)
Caucasian	1990 (n =827)	64.17	124.16	20.26	61.32
	1991 (n =767)	65.27	135.01	21.11	63.57
	1992 (n =711)	66.13	142.32	21.71	63.24
	1993 (n =636)	66.72	148.79	22.27	62.83
African American	1990 (n =247)	64.62	131.75*	21.14*	66.50*
	1991 (n =218)	65.62	142.03*	21.95*	67.68 $^{\Delta}$
	1992 (n =194)	66.30	150.19*	22.55*	67.53 $^{\Delta}$
	1993 (n =137)	66.72	155.71 $^{\Delta}$	23.02*	68.52 $^{\Delta}$

*$p < 0.01$ compared to Caucasians
$^{\Delta}$ $p < 0.05$ compared to Caucasians

SES differences were also found in this sample regarding body composition measurements (Table 18). Although the height and weight measurements were not found to be significantly different, significant differences regarding BMI and BMI percentile were shown.

For all study years, those in the middle SES group had higher BMI values compared to the high SES group; the difference however, was not found to be significant. The low SES group was found to have a significantly higher BMI value compared to the high SES group for study years 1990 ($p < 0.01$), 1991($p < 0.05$), and 1993 ($p < 0.01$). At baseline, the middle SES group was found to have a significantly lower BMI value (20.50 vs. 21.10) compared to the low SES group ($p < 0.05$). For the remaining years, the middle SES group had a lower BMI value compared to the low SES group, however, the findings were not significant.

Table 17: Body composition variables categorized by SES

SES	Year	Height (in)	Weight (lbs)	BMI (kg/m^2)	BMI Percentile (%)
Low SES	1990 (n =194)	64.07	128.93	21.10	71.38
	1991 (n =170)	65.15	138.60	21.76	69.84
	1992 (n =153)	65.88	145.93	22.32	67.64
	1993 (n =115)	66.29	152.37	23.03	71.77
Middle SES	1990 (n =575)	64.24	126.15	20.50⁺	66.87
	1991 (n =527)	65.31	137.04	21.46	69.76
	1992 (n =480)	66.19	144.25	21.94	67.27
	1993 (n =404)	66.77	151.67	22.50	67.85
High SES	1990 (n =305)	64.45	123.52	20.03 ж	62.88¤
	1991 (n =288)	65.54	134.49	20.85¤	64.43
	1992 (n =272)	66.31	142.49	21.71	65.99
	1993 (n =254)	66.85	146.32	22.14 ж	64.83¤

⁺ $p < 0.05$ middle compared to low
¤ $p < 0.05$ high compared to low
ж $p < 0.01$ high compared to low

Although not significant, the data illustrates a pattern showing the higher the SES group, the lower BMI percentile. For all study years, the high SES group had the lowest BMI percentiles and the low SES groups with the highest BMI percentiles. A significant ($p < 0.05$)

difference was only found when comparing the high SES group with a lower BMI percentile compared to the low SES group in 1990 (62.88 vs 71.38) and 1993 (64.82 vs. 71.77).

4.5 LONGITUDINAL CHANGES IN WEIGHT STATUS AND THE RELATIONSHIPS TO COVARIATES

In the study sample, the prevalence of obesity increased from 10.35% of the sample classified as overweight at baseline to 13.18% in 1993 (Table 17). The majority of adolescents were categorized in the healthy weight category in 1990 (73.54%), 1991 (71.24%), 1992 (72.20%) and 1993 (72.07%).

Table 18: Weight status for entire sample by each study year

Year	N	Healthy Weight (%)	At Risk (%)	Overweight (%)
1990	1074	73.54	16.11	10.35
1991	966	71.74	16.05	12.22
1992	892	72.20	15.70	12.11
1993	759	72.07	14.76	13.18

The percentage of 'healthy weight' adolescents was similar between males and females in 1990 (73.72% vs. 73.37%) and 1991 (71.09% vs. 72.45%). However, females were more likely to be categorized in the "at risk for overweight" group than males in 1990 (18.18% vs. 14.15%) and 1991 (16.92% vs. 15.25%) and males were more likely to be categorized in the "overweight" group than females in 1990 (12.48% vs. 8.10%) ($p < 0.05$) (Figure 6). Females were more often categorized as "healthy weight" in 1992 (75.81% vs. 68.83%) and 1993 (76.54% vs. 68.08%), while males were categorized more often as "overweight" (1992:15.37% vs. 8.6%; 1993: 16.71%

vs. 9.22%) and as “at risk for overweight” (1992: 15.8% vs. 15.58%; 1993:15.21% vs. 14.25%) compared to females ($p < 0.01$).

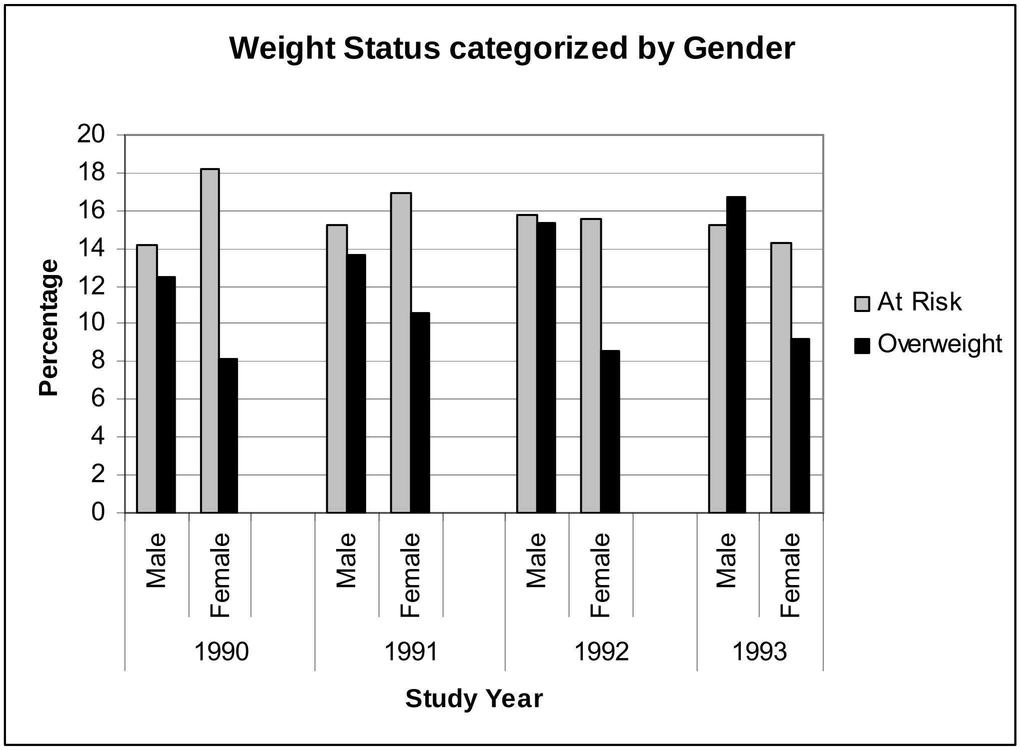

Figure 6: Percentage of adolescents in "At Risk for Overweight" or "Overweight" category at each time point by gender

Non-significant patterns were found regarding the weight status variables and race (Figure 7). Throughout all study years, Caucasian adolescents were more often categorized as a healthy weight status compared to African American adolescents (data not shown on figure). Although not significant, African American adolescents were more often classified as being "overweight" compared to Caucasian adolescents in all study years. No significant patterns were found among racial group and those classified as "at risk for overweight" for years 1990-1993. Throughout all study years, the percentage of healthy weight adolescents decreased as SES level decreased and percent of adolescents in the "overweight" category increased as SES level decreased, although these findings were not significant (Figure 8).

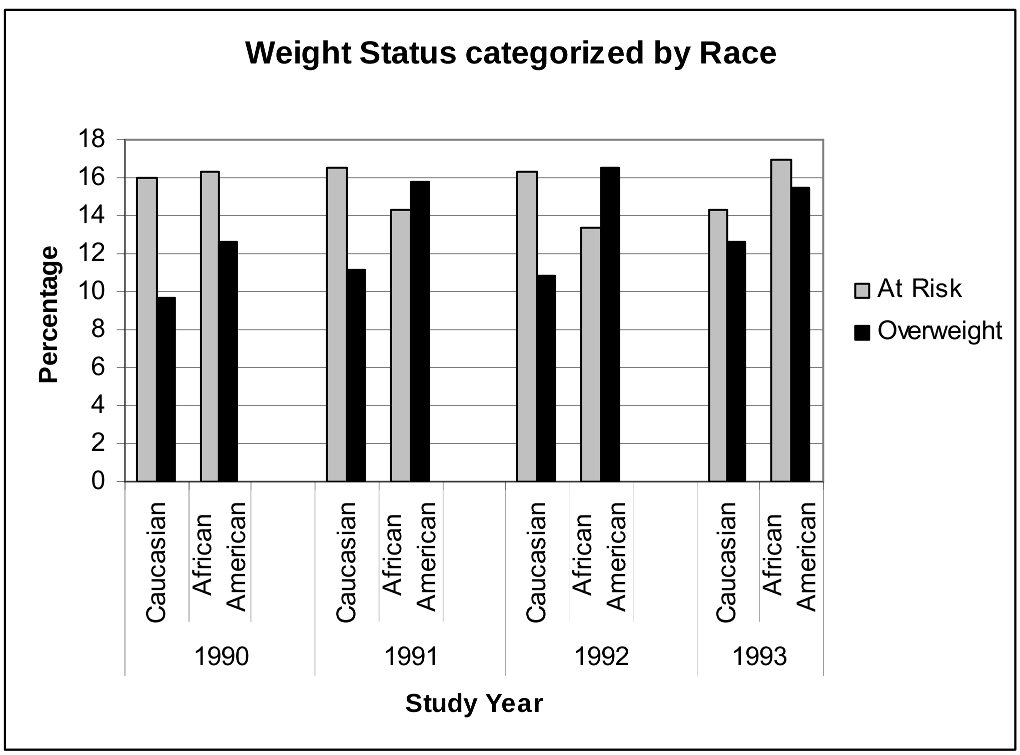

Figure 7: Percentage of adolescents in "At Risk for Overweight" or "Overweight" category at each time point by race

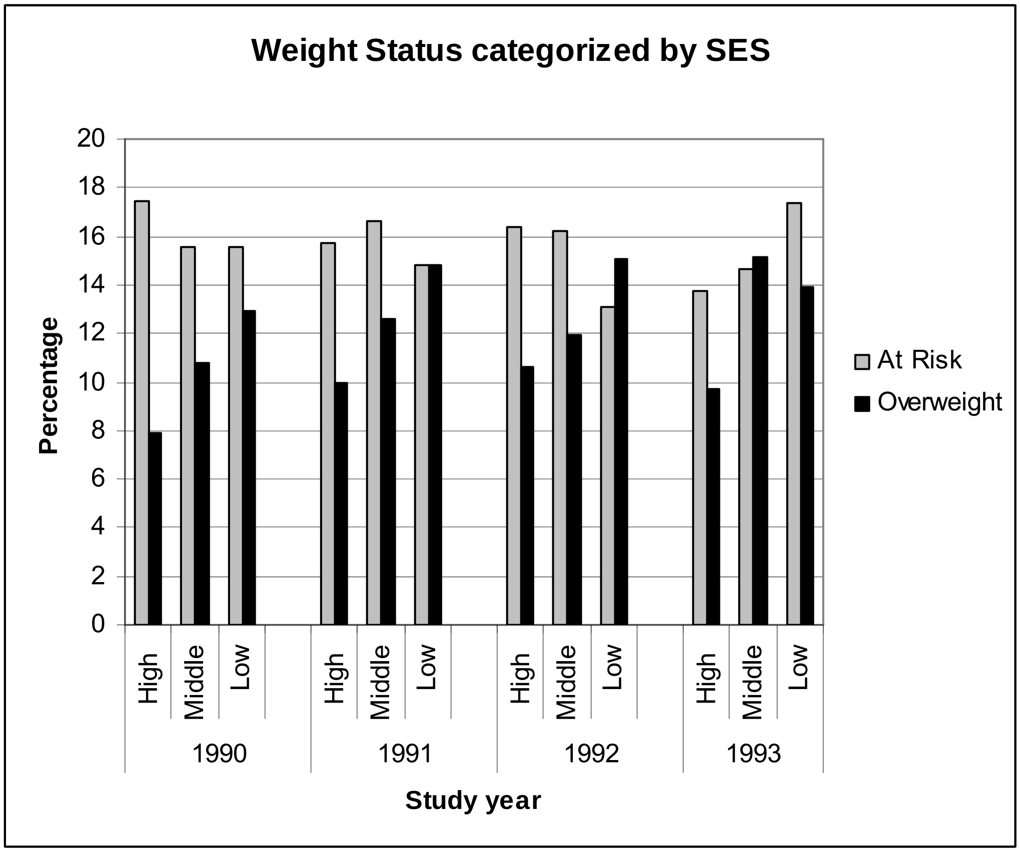

Figure 8: Percentage of adolescents in "At Risk for Overweight" or "Overweight" category at each time point by SES

4.6 LONGITUDINAL ANALYSIS OF THE EFFECT OF PHYSICAL ACTIVITY TO WEIGHT STATUS

To examine the relation between physical activity and weight status, two separate analyses were conducted: same-year effect PA and lag-year effect PA. For these analyses a generalized mixed model was conducted using GLIMMIX (SAS, Inc.) in order to account for both the random and fixed effects. The first analysis, same-year effect PA, examined the relation of weight status from the physical activity measured in the same year. While the second analysis, the lag-year effect PA, examined weight status from the physical activity measured during the previous year. Prior to both of these analyses, all missing data was imputed using PROC Multiple Imputations (SAS, Inc.)

4.6.1 Same-year effect PA analysis

For the same-year effect PA analysis, the odds ratio (OR) of being categorized "at risk for overweight" or "overweight" compared to a "healthy weight" was examined. The effect on BMI percentile, by the physical activity measured during the previous year, was also examined. The odds of "at risk for overweight" compared to being a "healthy weight" can be found in Table 20. There was insufficient evidence to support the main hypothesis that physical activity affected weight status in the same-year effect PA analysis (OR = 1.00; 95% CI 0.99, 1.01). Thus the amount of physical activity one participated in during each study year did not increase the odds of being categorized as "at risk for overweight" compared to a "healthy weight".

Table 19: Longitudinal results predicting the odd ratios of being "At Risk for Overweight" by the amount of physical activity that year

Variables	β	γ	SE	OR	95% CI for the OR
PA	<0.01	0.02	0.01	1.00	(0.99, 1.01)
Year 1993	-0.25	0.02	0.21	0.78	(0.52, 1.17)
Year 1992	-0.09	0.02	0.21	0.91	(0.61, 1.38)
Year 1991	-0.13	0.02	0.21	0.88	(0.59, 1.32)
Female	0.67	0.06	0.22	1.96	(1.27, 3.02)
African American	-0.15	0.04	0.28	0.86	(0.50, 1.48)
SES – High	-0.28	0.09	0.36	0.76	(0.38, 1.52)
SES – Middle	-0.14	0.01	0.26	0.87	(0.53, 1.44)

Using 1990 as a reference year, the years 1991-1993 were examined to see if the odds of being "at risk for overweight" changed in one particular year. The results indicate that the odds of being "at risk for overweight" did not significantly change over the four years. A significant relation was found by gender. Females were 1.96 times more likely to be in the "at risk for overweight" category rather than the "healthy weight" category compared to males (OR = 1.96; 95% CI 1.27, 3.02). Neither a racial nor SES effect was found; however, the results illustrate that as SES increased, the odds of being categorized as "at risk for overweight" compared to a "healthy weight" decreased.

The odds of being "overweight" compared to being of a "healthy weight" can be found in Table 21. There was insufficient evidence to support the main hypothesis that physical activity affected weight status in the same-year effect PA analysis (OR = 1.00; 95% CI 1.0, 1.01). Therefore, the amount of physical activity one participated in during that study year did not increase the odds of being categorized as "overweight" compared to a "healthy weight". No gender or racial differences were found regarding those being categorized as "overweight" compared to a "healthy weight". Although not significant, it appears from this analysis that as

SES increased, the odds of being categorized as "overweight" compared to a healthy weight decreased.

Table 20: Longitudinal results predicting the odd ratios of being "Overweight" by the amount of physical activity that year

Variables	β	γ	SE	OR	95% CI for the OR
PA	<0.01	0.05	<0.01	1.00	(1.00, 1.01)
Year 1993	-0.06	0.23	0.12	0.94	(0.75, 1.19)
Year 1992	-0.02	0.11	0.12	0.98	(0.78, 1.23)
Year 1991	-0.08	0.02	0.11	0.92	(0.74, 1.15)
Female	0.04	0.09	0.13	1.04	(0.80, 1.35)
African American	<0.01	0.03	0.17	1.00	(0.72, 1.40)
SES – High	-0.07	0.01	0.22	0.93	(0.61, 1.42)
SES – Middle	-0.01	0.01	0.15	0.99	(0.73, 1.33)

The effect of BMI percentile on weight status was also examined (Table 22). Due to the use of linear regression modeling, physical activity data were transformed into a normal distribution for this analysis. Overall, no significant relation was found between physical activity and BMI percentile (β = -0.03; 95% CI -0.10, 0.03). BMI percentile increased significantly compared to baseline in years 1991 (β = -0.20; 95% CI -0.27, -0.13), 1992 (β = -0.17; 95% CI -0.24, -0.10), and 1993 (β = -0.17; 95% CI -0.24, -0.10). No significant effects were found regarding gender, race or SES.

Table 21: Longitudinal results predicting the effects of BMI percentile by the amount of physical activity that year

Variables	β	γ	SE	95% CI for β
tPA*	-0.03	0.27	0.03	(-0.10, 0.03)
Year 1993	-0.17	0.39	0.04	(-0.24, -0.10)
Year 1992	-0.17	0.26	0.04	(-0.24, -0.10)
Year 1991	-0.20	0.06	0.04	(-0.27, -0.13)
Female	0.08	0.18	0.14	(-0.19, 0.35)
African American	-0.30	0.08	0.18	(-0.66, 0.05)
SES – High	-0.40	0.15	0.23	(-0.85, 0.05)
SES – Middle	-0.19	0.18	0.16	(-0.51, 0.13)

* data was transformed into a normal distribution

4.6.2 Lag-year effect PA analysis

For the lag-year effect PA analysis, the odds of being categorized as "at risk for overweight" or "overweight" compared to a healthy weight were examined. The effect of BMI percentile, by the physical activity measured during the previous year, was also examined. The odds of being "at risk for overweight" compared to being of a "healthy weight" can be found in Table 23. There was insufficient evidence to support the main hypothesis that physical activity affected weight status in the lag-year effect PA analysis (OR = 1.01; 95% CI 0.99, 1.02). The amount of physical activity one participated in during the previous year did not increase the odds of being categorized as "at risk for overweight" compared to a being categorized as a "healthy weight". A significant relation was found by gender. Females were 1.99 times more likely to be in the "at risk for overweight" category rather than the "healthy weight" category compared to males (OR = 1.99; 95% CI 1.30, 3.03). No gender or racial differences were found regarding those categorized as "at risk for overweight" compared to a "healthy weight". Although not significant, it appears from this analysis that as SES increased, the odds of being categorized as "at risk for overweight" compared to a healthy weight decreased.

Table 22: Longitudinal results predicting the odd ratios of being "At Risk for Overweight" by the amount of physical activity previous year

Variables	β	γ	SE	OR	95% CI for the OR
lagPA	0.01	0.05	0.01	1.01	(0.99, 1.02)
Year 1993	-0.08	0.01	0.18	0.93	(0.65, 1.32)
Year 1992	0.04	0.02	0.18	1.04	(0.73, 1.49)
Female	0.69	0.10	0.22	1.99	(1.30, 3.03)
African American	-0.13	0.06	0.27	0.88	(0.52, 1.48)
SES – High	-0.24	0.11	0.34	0.78	(0.40, 1.54)
SES – Middle	-0.14	0.03	0.25	0.87	(0.54, 1.41)

The odds of being "overweight" compared to being of a "healthy weight" can be found in Table 24. There was insufficient evidence to support the main hypothesis that physical activity affected weight status in the lag-year effect analysis (OR = 1.00; 95% CI 1.0, 1.01). This indicates that the amount of physical activity one participated in the previous study year did not increase the odds of being categorized as "overweight" compared to a "healthy weight". No gender or racial differences were found regarding those being categorized in the "overweight" category compared to the "healthy weight" category. Although not significant, it appears from this analysis that as SES increased, the odds of being categorized as "overweight" compared to a healthy weight decreased.

Table 23: Longitudinal results predicting the odd ratios of being "Overweight" by the amount of physical activity previous year

Variables	β	γ	SE	OR	95% CI for the OR
lagPA	<0.01	0.14	<0.01	1.00	(1.00, 1.01)
Year 1993	0.03	0.20	0.12	1.03	(0.82, 1.29)
Year 1992	0.06	0.08	0.12	1.06	(0.85, 1.34)
Female	0.12	0.12	0.14	1.13	(0.86, 1.50)
African American	0.05	0.03	0.18	1.05	(0.74, 1.50)
SES – High	-0.15	0.02	0.22	0.86	(0.55, 1.33)
SES – Middle	-0.07	0.01	0.16	0.93	(0.68, 1.28)

The effect of BMI percentile on weight status was also examined (Table 25). Overall, no significant relation was found between physical activity reported the pervious year and BMI percentile (β = 0.03; 95% CI -0.04, 0.11). Although not significant, males tended to have higher BMI percentiles than females.

Table 24: Longitudinal results predicting the effects of BMI percentile by the amount of physical activity previous year

Variables	β	γ	SE	95% CI for β
lagtPA*	0.03	0.14	0.04	(-0.04, 0.11)
Year 1993	0.05	0.52	0.04	(-0.02, 0.12)
Year 1992	0.04	0.39	0.03	(-0.02, 0.11)
Female	0.21	0.14	0.14	(-0.07, 0.48)
African American	-0.29	0.11	0.18	(-0.65, 0.07)
SES – High	-0.31	0.18	0.23	(-0.76, 0.15)
SES – Middle	-0.18	0.10	0.17	(-0.51, 0.14)

* data was transformed into a normal distribution

4.7 ADDITIONAL LONGITUDINAL ANALYSES REGARDING RELATION BETWEEN PHYSICAL ACTIVITY AND WEIGHT STATUS

A relation between physical activity and weight status was further explored by various methods. To examine physical activity and the relation of weight status overtime, a one year lag effect was examined in the main analyses. The results indicated no significant relationship. To further examine if physical activity over time affected weight status a GLIMMIX lag effect model was conducted both at a two and three year period. Using the same model as the one year lag effect reported above, physical activity reported in 1990 and 1991 was evaluated using weight status two years later, in 1992 and 1993, respectively, as well as physical activity in 1990 compared to weight status three years later, in 1993. The results of the analysis were unchanged.

4.8 SUMMARY OF RESULTS

Total physical activity for both males and females declined over the four study years, 43% and 14%, respectively ($p < 0.01$). Males reported significantly ($p < 0.01$) more median hrs/wk of total PA compared to females. Throughout all study years Caucasian adolescents reported a greater amount of median hrs/wk of total physical activity compared to those classified as African American ($p < 0.05$). Although not all relationships were found to be significant, generally, as SES level increased, the amount of physical activity increased, with the lowest SES group reporting the least amount of physical activity.

In the study sample, prevalence of obesity increased from 10.35% of the sample classified as “overweight” at baseline to 13.18% in 1993. In 1990-1991 females were more likely to be categorized in the “at risk for overweight” group than males and males were more likely to be categorized in the “overweight” group than females ($p < 0.05$). In 1992-1993 males were categorized more often as “at risk for overweight” and “overweight” compared to females ($p < 0.01$). No significant patterns were found among racial group and weight status; however, throughout all study years adolescents categorized as Caucasian were more often categorized as a “healthy weight” status compared to African American adolescents. Also, African American adolescents were more often classified as being “overweight” compared to Caucasian adolescents in all study years, although not significant. Throughout all study years, the percentage of “healthy weight” adolescents decreased as SES level decreased and percent of adolescents in the “overweight” category increased as SES level decreased, although these findings were not significant.

For the same-year and lag-year effect PA analysis, the odds of being categorized “at risk for overweight” or “overweight” compared to a “healthy weight” was examined as well as an examination of the effect on BMI percentile, by the reported amount of physical activity. There was insufficient evidence to support the main hypothesis that physical activity affected weight status in the same-year or lag-year effect PA analyses. Thus the amount of physical activity one participated in did not increase the odds of being categorized as “at risk for overweight” or “overweight” compared to a “healthy weight”. Although neither racial or SES effects were found to be significantly related to weight status, gender differences were discovered. Females were twice as likely to be in the “at risk for overweight” category compared to the “healthy weight” category compared to males.

5.0 DISCUSSION

5.1 INTRODUCTION

The purpose of this study was to examine the relation of physical activity to weight status in adolescents over a four year time period. This section is composed of the following sections: (5.2) Discussion of Results, (5.2) Conclusions, and (5.4) Recommendations for the Future.

5.2 DISCUSSION OF RESULTS

The findings of this longitudinal study indicate that there was no significant relation between physical activity and weight status in this sample of adolescents over the four year study period. These results were unexpected as the majority of longitudinal studies have found a relationship between these variables.[35, 58, 70-72] Although two of these studies used a younger aged sample (3.9-5.6 years)[58, 71] and thus do not coincide with the current study under investigation, the remaining four studies used adolescent samples.

Literature has shown that as physical activity declines over adolescence, fluctuations in body composition (measured via BMI, percent body fat and skinfolds) may occur with in as little as one year.[35, 70, 72] Berkey et al. followed adolescents for one year assessing their dietary intake, physical activity, sedentary time and height/weight.[70, 72] Results indicated that large increases in

BMI were found among girls who reported high caloric intakes, less physical activity and more sedentary time and for boys who reported more sedentary time. Kimm et al found similar results over ten years. This study found that for every 10 MET decline of physical activity both BMI value and skinfold thickness increased.[35] Studies on the other hand, have found that weight status and physical activity may not be inversely related during adolescence.[28, 69] One in particular, Kettaneh et al., found that females in the highest level of physical activity at baseline, predicted the highest gain in all adiposity indicators (percent body fat and skinfolds data) at baseline.[28] Adolescents for this study were non-obese at baseline and were assessed at baseline and one follow-up, two years later, for both height/weight and physical activity (via the MAQ). On the other hand, Elgar et al. followed a similar aged sample as the current study under discussion for four years and found that sedentary time predicted the change in BMI rather than physical activity. Thus, research in this area is equivocal and future research needs to further investigate the association between physical activity and weight status.

A few reasons may explain why this current study did not find an inverse relationship between physical activity and weight status. One reason could be that only 27 % of the sample changed weight status categories over the four years, which may have limited the ability to examine any relationship. Perhaps a relationship may have been found using only those adolescents who were categorized as a healthy weight at baseline.

Weight status was determined using BMI criteria for children and adolescents. Although, BMI has been shown to be a valid screening tool for weight status categories among adolescents, BMI should be used cautiously when comparing BMI values across different aged adolescents.[101] Research has shown that BMI tracks linearly with percent body fat; however, can not accurately predict changes in body fat, especially during the adolescent growth period. This analysis did not include data regarding body fat distribution specifically, which may have determined if the percentage of body fat was changing overtime, while weight status remained the same. Research has shown that increased levels of physical activity during the pre-pubertal years leads to a decrease in the amount of body fat during the adolescent years.[71] As previously reported, changes in body fat distribution naturally occur during the adolescence time period.[28] Having this information in the analysis may have helped to explain the relationship of physical activity and weight status. A relationship may have been found regarding body composition as increases in the amount of fat tissue could have been attributed to the declining levels of physical activity.

Other studies have evaluated the role of diet, along with physical activity, when examining changes in weight status as dietary intake is a key contributor to the obesity epidemic. In the current study, dietary data were not collected, therefore significant increases or decreases in the amount of calories this sample was consuming on a regular basis was not known. Perhaps the changes in weight status were attributed to a change in daily caloric consumption.

Lastly, sedentary time was not accounted for in this study which could have contributed to the lack of a relationship between physical activity and weight status. Studies have reported that sedentary time during adolescents impacted weight status more so than physical activity.[102, 103] Specifically, research has shown that weight status and inactive time are related, as physical activity decreases, inactive time increases.[69, 70, 72, 104, 105] Other studies have found that the amount of inactive or sedentary time, rather than hours of physical activity is a more accurate indicator of weight status in adolescents.[102, 103] Epstein et al suggests that altering sedentary behavior results in a positive influence of changing both physical activity levels and total caloric intake.[106] Sedentary time can effect ones weight by a variety of mechanisms.[107, 108] Television time has been found to increase energy intake, lower energy expenditure and overall lower one's activity level. The literature has also reported that physical inactivity time carries over into adulthood.[32, 41] This finding exemplifies the importance of preventing the decrease of physical activity that occurs during adolescence,[27-30, 32] with the intention to reduce sedentary time.[28, 72]

This study had many strengths including the use of a valid and reliable adolescent physical activity questionnaire, a large sample of diverse adolescents, and the repeated assessments of physical activity and body composition measurements over four years. Both, physical activity and body composition (height and weight) were assessed annually over four years by a member of the research staff to ensure accuracy of the measurement. A major strength of this study was the use of advanced statistical methods in the analysis to impute missing data. By using the SAS, Inc. statistical method, multiple imputation, this study was able to calculate all missing data values prior to the analyses for all 1098 adolescents. Lastly, throughout the statistical analysis weight status was analyzed as both a continuous and categorical variable in order to be sensitive to the arbitrary cut-off points between weight status categories.

Despite its' many strengths, this analysis was not without limitations. First, the main predictor variable, physical activity was measured via self report. Although the MAQ was found to be both valid and reliable in this sample of adolescents[109], self report is a subjective measure with individual biases. When an individual completes a survey or questionnaire many cognitive processes occur. First an individual interprets the question, next one retrieves and forms a response from memory, then, makes a judgment of how the answer should be formed and finally a response is given.[110] This retrieval of information elicits overestimating or underestimating the desired behavior, recall basis, and social desirability concerns.[111] An objective measure of physical activity would have been more ideal, although expensive with this large sample of adolescents. Secondarily, although sedentary time data were collected in the original study, it was not included in the current analysis. Dietary data was not a part of the original study which was also a limitation. Finally, as found in other longitudinal data sets, missing data points are extremely common. Although this analysis used a validated mathematically method to impute missing data values, a complete data set would have been more accurate.

This current study was unique in that it compared the individual weight status categories: healthy weight, at risk for overweight and overweight, while the majority of previous studies focused specifically on changes in body fat distribution and/or skinfold measurements. While the current study did not find a relation between physical activity and weight status, many similarities exist between previously reported studies and this longitudinal study. For example, this study confirms the disparities between physical activity and gender. In conjunction with other studies, this study found that gender influences physical activity with females reporting the least amount of activity.[27-30, 32] A steady decline in physical activity was shown among both males and females throughout the adolescence period, which also corresponds with previous literature.[27-30, 34, 41, 42] Among this sample as in other studies, significant differences among racial groups were found showing that African American adolescents report less physical activity compared to Caucasian adolescents.[14, 34-36] Social economic status differences also existed among this sample of adolescents. As found in other studies, those categorized as having low SES were significantly less active and more overweight than adolescents in either the middle or high SES category.[16, 105, 112]

5.3 CONCLUSIONS

The purpose of the current study was to examine the relation of physical activity to weight status in a sample of adolescents over a four year time period. To determine if a relationship existed among weight status and physical activity, 1098 males and females, with a mean age of 13.5 years were investigated. After adjusting for potential covariates, gender, SES and race, no relationship was found between physical activity and weight status. In conclusion, this study did not support the hypothesis that decreasing physical activity is related to weight status during adolescence. Conclusions can be made however, regarding the relationships between the covariates (gender, race and SES group) and both the amount of physical activity and weight status category. This study confirms the disparities that exist among gender, race and SES level in regards to physical activity and obesity. Overall, males, Caucasians and those in the high SES group reported the highest amount of physical activity. Neither racial nor SES differences were found regarding weight status in this sample; however, males were more often categorized in the higher weight status categories compared to females. Further investigation of lifestyle factors, such as physical activity, sedentary time, diet, etc., among adolescents in relation to weight status is needed to further elucidate the association between these variables. A better understanding of the role of physical activity in the development of obesity may help in the prevention and treatment of obesity.

5.4 RECOMMENDATIONS FOR THE FUTURE

The findings of the current study suggest several recommendations for future epidemiological studies examining the relation between physical activity and weight status among adolescences.

1. Future studies should utilize objective methods to measure physical activity such as an activity monitor, motion sensors or pedometers.
2. Data should include inactive time as well as physically active time.
3. Dietary intake should be measured to account for changes in caloric intake.
4. A larger study sample is needed to evaluate the effects of physical activity on the pattern of weight status.
5. Statistical methods should be researched in order to account for normal increases in BMI that occur during adolescence.
6. Body fat distribution should be included among other body composition measures (height, weight, BMI, BMI percentile, etc).

APPENDIX A

LIST OF THE OUTPATIENT CLINICAL WEIGHT MANAGEMENT PROGRAMS IN THE UNITES STATES

Outpatient Clinic	Services Offered	Staffing In Place
Cincinnati Children's Hospital: Health Works!	– Ages 5-19 years – Behavioral/nutritional/exercise counseling – Bariatric surgery – Group exercise program (for a fee)	– M.D./nurse – Surgeons – Dieticians/Exercise Physiologists – Psychologists
Children's Hospital of Wisconsin: New Kids	– Ages 2-18 years – Individual counseling or group classes	– Local YMCA – Cardiologist/Nurse – Dietician/Ex.Phys – Psychologist
Connecticut Children's Hospital: TEAM Club	– Ages 6-9 years – 8 week group classes including entire family – Fee for group classes	– Psychologist – Dietician – Physical Therapist – Endocrinologist
Children's Hospital of the King's Daughters: Healthy You	– Ages 8-18 years – Group classes – Fee for services	– Social worker – Dietician – Physical or Occupational therapist
John's Hopkins Children's Center	– Ages 8-18 – Monthly group classes	– Pediatricians – Dietician – Psychologist
Children's Hospital of Boston: Optimal Weight for Life (OWL)	– Group sessions – Nutrition and exercise counseling – Behavioral modification	– M.D. – Nurse – Dieticians – Psychologist
The Children's Medical Center of Dayton: The Body Shop	– Ages 8-18 years – Small weekly group classes – Fee for classes	– Dietitian – Exercise Physiologist – Psychologist
Atlanta Children's FIT KIDS	– Ages 6-12 – Educational programs: using pedometers, playing fun activities – Fee for service	– N/A
Children's Health System Alabama: Let's Eat Smart and Then Exercise Right (LESTER)	– Ages 6-11 years – Group classes – Fee for classes	– Dietitian – Child Life Therapist – Occupational Therapist
Children's Hospital of Philadelphia	N/A	N/A
Rainbow Babies (Cleveland Children's Hospital)	– Fitness training/lifestyle and dietary medications	N/A
Children's Columbus Ohio	– Ages 8-12 years – 4 week group classes – Fee for classes	N/A
Children's Hospital of Pittsburgh	– Ages 0-21 – Individual and group counseling – Nutrition/exercise/behavioral medication	– M.Ds/Physican Assistant – Dieticians/ExPhys – Behavioral Therapists – Nurses/Medical Assistant

APPENDIX B

PAST YEAR LEISURE-TIME PHYSICAL ACTIVITY QUESTIONNAIRE

PAST YEAR LEISURE-TIME PHYSICAL ACTIVITY

Check all activities that you did at least ten times in the **PAST YEAR**. Do not include time spent in school physical education classes. Make sure you include all sport teams that you participated in during the last year.

___ Aerobics
___ Band/ Drill Team
___ Baseball
___ Basketball
___ Bicycling
___ Bowling
___ Cheerleading
___ Dance Class
___ Football
___ Garden/ Yard Work

___ Gymnastics
___ Hiking
___ Ice Skating
___ Roller Skating
___ Running for Exercise
___ Skateboarding
___ Snow Skiing
___ Soccer
___ Softball
___ Street Hockey

___ Swimming (Laps)
___ Tennis
___ Volleyball
___ Water Skiing
___ Weight Training
___ Wrestling (Competitive)

Others

____
____
____

List each activity that you checked above in the "Activity" box below, check the months you did each activity and then estimate the amount of time spent in each activity.

Activity	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Months Per Week	Days Per Week	Minutes Per Day

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