ACTIVE HEALTHY TEENS:

MEETING PHYSICAL ACTIVITY GUIDELINES AND THE RISK OF OVERWEIGHT IN ADOLESCENTS

By

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ABBREVIATIONS

AAP – American Academy of Pediatrics

ADOLPA - Social Influences on Adolescent Physical Activity Study

BMI - Body mass index

CI - Confidence interval

IRB - Institutional Review Board

NHANES - National Health and Nutrition Examination Survey

OHSU – Oregon Health and Science University

OR - Odds Ratio

ORI – Oregon Research Institute

WHO – World Health Organization

YRBS – Youth Risk Behavior Survey

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ABSTRACT

Background: Childhood and adolescent obesity is an increasingly significant problem in the United States. Inadequate physical activity is hypothesized to be a major contributing factor to this epidemic; however, the evidence linking physical activity patterns and obesity in youth is inconsistent. By using pedometers to objectively measure physical activity, the Social Influences on Adolescent Physical Activity (ADOLPA) study conducted by Oregon Research Institute from 1999-2007 provides a unique opportunity to more accurately characterize the association between physical activity and obesity.

Objective: To examine whether meeting recommended physical activity standards of 60 minutes per day of moderate to vigorous activity as measured by pedometer is associated with overweight status in adolescents aged 10-14 years.

Design and Methods: A cross sectional analysis was conducted using baseline data from the ADOLPA Study (). All study subjects wore a pedometer for a week, reporting daily number of steps to objectively measure physical activity, in addition to answering an extensive survey. Physical activity levels were defined as Low: less than 10,000 steps per day, Moderate: 10,000 to 12,000 steps per day for girls, 10,000-13,000 steps per day for boys, or High: at least 12,000 steps per day for girls or 13,000 steps per day for boys. The main outcome variable was body mass index (BMI)-for-age percentile divided into two categories: normal weight ($<85^{th}$ percentile) and overweight (including obese)($\geq 85^{th}$ percentile). Prevalence of adolescents meeting physical activity levels and prevalence of overweight and obesity were determined. Correlations between pedometer recording and self-report measures of physical activity were assessed. The association between physical activity and overweight was assessed using multivariate logistic regression to control for potential confounders.

Results: The participants include a total of 371 adolescents aged 10-14 years, 24% of whom were from minority backgrounds.Overall, 44.7 % of the sample was classified as overweight with a BMI-for-age at the 85^{th} percentile or higher, and 23.0% were classified as obese with BMI-for-age at the 95^{th} percentile or higher. There were no significant differences in weight status by age or sex. 26.9 % of the sample met the highest level of physical activity. Girls were significantly more likely than boys to only achieve the lowest level of activity (61% vs. 41%). Three survey questions on physical activity were only weakly correlated with pedometer recordings (r=0.24). Adolescents reporting more or much more exercise than their peers were less likely to be overweight (OR 0.62, 95% CI (0.45, 0.85), p=0.003). The risk of overweight was highest among adolescents in the lowest physical activity level (53.7%) compared with those in the moderate level (41.8%) and the highest level (29.6%). After adjusting for television viewing, household income and sex, the odds ratios (OR, 95% CI) for overweight were 0.64 (0.37, 1.11) for those in the moderate physical activity level (p=0.12), and 0.38 (0.22, 0.66) for those in the highest activity level (p< 0.001). Television viewing was also associated with overweight status, with adjusted odds ratios of 1.7 (1.02, 2.9) for adolescents watching 2-3 hours a day (p = 0.043), and OR of 2.2 (1.01, 3.2) for those watching 4 or more hours a day compared to those watching less than 2 hours a day (p=0.048). Adolescents in households earning more than the median income of $50,000 per year had lower odds of overweight with OR of 0.64 (0.42, 0.99) (p=0.045).

Conclusions: Inadequate physical activity, television viewing, and lower socioeconomic status are associated with an increased risk of overweight and obesity for adolescents. Studies evaluating prevention strategies targetting physical activity and sedentary behavior are needed to reduce the prevalence of overweight and obesity among adolecents.

Background

Childhood obesity is a serious and growing problem in the US. The most recent estimates from the National Health and Nutrition Examination Survey (NHANES) identify 12.4 percent of children two to five years of age, 17.0 percent of children six to 11 years of age, and 17.6 percent of adolescents 12 to 19 years of age in America as obese, with body mass index (BMI) at or above the 95th percentile of the CDC growth charts, and 31.9% of children age 2-19 as overweight with BMI at or above the 85th percentile(Ogden, Carroll, & Flegal, 2008). This prevalence has tripled since the 1960s, prompting the World Health Organization (WHO) to declare childhood obesity a global epidemic (Diet, nutrition and the prevention of chronic diseases.2003). Childhood obesity has many health implications including increased incidence of type 2 diabetes, hypertension, and sleep apnea, as well as decreased self esteem(Rosenbloom, 2002)(Sorof, Lai, Turner, Poffenbarger, & Portman, 2004)(Wing et al., 2003)(Schwimmer, Burwinkle, & Varni, 2003). Unfortunately, these problems continue past adolescence. Adolescent obesity increases the long-term risk of adult morbidity and mortality, independent from adult obesity, as shown in long term cohort studies (Must, Jacques, Dallal, Bajema, & Dietz, 1992). Additionally, more than 70% of obese adolescents become obese adults (Whitaker, Wright, Pepe, Seidel, & Dietz, 1997). Adult obesity is associated with many poor health outcomes including diabetes, hypertension and dyslipidemia, all of which increase the risk for coronary artery disease, the leading cause of death in the US (Council on Sports Medicine and Fitness & Council on School Health, 2006).

Although many factors are thought to influence childhood obesity including genetics and diet, it is hypothesized that inadequate physical activity and sedentary behaviors are major contributors to the obesity epidemic (Council on Sports Medicine and Fitness & Council on School Health,

2006) (Hill & Peters, 1998)(Eisenmann, Bartee, Smith, Welk, & Fu, 2008). While inadequate physical activity is clearly linked to obesity in adults, there is inconsistent evidence linking physical activity to weight status in children and adolescents. A comprehensive review of studies found that only 16 of 31 studies (52%) in children aged 4-12 years and 6 of 21studies (29%) in adolescents aged 13-18 years found significant association between physical activity and BMI (Sallis, Prochaska, & Taylor, 2000). All of these studies have been cross sectional and most measured physical activity by self report, which tends to overestimate physical activity and may explain the inconsistencies in the evidence (Sallis et al., 1996) (Sallis, Buono, Roby, Micale, & Nelson, 1993).

More recent studies using objective measures of physical activity point to an association between physical activity and obesity. A large cross-sectional study in 2004 using accelerometers to measure physical activity in 878 11-15 year olds found that failing to meet the guidelines of 60 min/day of moderate to vigorous physical activity was associated with overweight status in both boys and girls(Patrick et al., 2004). In 2008, a cohort study objectively measuring physical activity and obesity related health outcomes for 5-8 year olds found that meeting physical activity guidelines was associated with improvements in metabolic health (insulin sensitivity, triglycerides, cholesterol and blood pressure) but was not associated with change in BMI or skin fold thickness (Metcalf, Voss, Hosking, Jeffery, & Wilkin, 2008). There are no similar longitudinal studies on adolescents (Metcalf et al., 2008). More research is needed to better understand the associations between physical activity and obesity in adolescents.

Despite the lack of definitive evidence linking physical activity in childhood and adolescence to healthy weight, increasing physical activity is seen as a way to intervene in the obesity epidemic. In order to prevent childhood obesity, new guidelines proposed by the US Department of

Agriculture and the American Academy of Pediatrics recommend 60 minutes per day of moderate to vigorous physical activity for children and adolescents (Council on Sports Medicine and Fitness & Council on School Health, 2006). Yet few adolescents are meeting these recommendations. National survey data from the Youth Risk Behavior Surveillance (YRBS) from 2007 indicate that only 43.7% of male and 25.6% of female high school students met these recommended levels of physical activity (Eaton et al., 2008). Even more discouraging, physical activity decreases significantly as adolescents progress through the teen years (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008)(S. C. Duncan, Duncan, Strycker, & Chaumeton, 2007).

Most studies, including the YRBS, use self report questionnaires to determine physical activity levels, and may overestimate the true level of physical activity (Sallis et al., 1993). Pate found that the prevalence of high school students meeting physical activity guidelines when measured objectively was dramatically lower than the prevalence rates found by the self report questions on the YRBS(Pate et al., 2002). Pedometers are an accurate and cost effective method to objectively measure physical activity and a major improvement over self-report measures (Tudor-Locke et al., 2004) (Strycker, Duncan, Chaumeton, Duncan, & Toobert, 2007) (Rowlands & Eston, 2005). The American Academy of Pediatrics policy statement on prevention of childhood obesity through increased physical activity (2006) recommends using pedometers to track physical activity, as they are simple, inexpensive, more objective, and "have a gadget appeal among youngsters"(Council on Sports Medicine and Fitness & Council on School Health, 2006). While adults are recommended to accumulate 10,000 steps per day for a healthy lifestyle(Council on Sports Medicine and Fitness & Council on School Health, 2006) (Tudor-Locke et al., 2004), the recommendations for youth are less clearly defined, ranging from 11,000-13,000 steps per day for girls and 13,000 to 16,000 steps per day for boys(Tudor-Locke et al., 2004) (Rowlands & Eston, 2005) (J. S. Duncan, Schofield, & Duncan, 2007)(Tudor-Locke, Hatano, Pangrazi, & Kang, 2008)(President's Council on Physical Fitness and Sports, 2005). In order to assess the number of steps per day needed to meet the physical activity guidelines, Rowlands (2005) compared accelerometer and pedometer recordings for children age 8-10, and found that boys should accumulate 13,000 steps per day and girls need 12,000 steps per day to achieve 60 minutes per day of moderate activity (Rowlands & Eston, 2005).

In the present study, the overall risk of overweight status is described for a group of 371 adolescents aged 10-14 who were subjects in the Oregon Research Institute Social Influences on Adolescent Physical Activity (ADOLPA) Study at baseline in 1999-2000. An improvement over previous self-report studies, this study used pedometers to objectively measure subjects' physical activity and assessed the association between physical activity and overweight with BMI as the outcome variable. Age, sex, race, household income, parent's education level, family structure, television and screen time, access to parks, and diet are evaluated as possible confounding exposures. As previous research has shown that girls, minorities and older teens have lower levels of physical activity, (S. C. Duncan et al., 2007; Eaton et al., 2008; Kimm et al., 2002; Nader et al., 2008), we explored age, race and gender as possible effect modifiers of increased risk of overweight due to physical inactivity. If these factors contribute to a large portion of increase in risk, interventions could target these populations.

Specific Aims

This study addressed three specific aims:

1. Quantify the prevalence of adolescents classified as overweight and obese and the prevalence of those meeting physical activity standards in 10, 12 and 14 year old age groups, and in boys and girls. The present study should provide more accurate prevalence estimates than self report studies, as both BMI and physical activity are objectively measured.

   Hypothesis: Girls and older adolescents will have lower prevalence for physical activity.

2. Examine the correlation between self report of physical activity and pedometer data. The present study provides an opportunity to compare the accuracy of self report questionnaires to pedometer measurement of activity over the same time period.

   Hypothesis: Correlation between self report and pedometers will be weak to moderate.

3. Examine the association between meeting physical activity standards and overweight status adjusting for potential confounding variables.

   Hypothesis: Adolescents are more likely to be overweight if they are not meeting recommended guidelines of a minimum number of steps/day.

Since childhood obesity is a significant and growing problem in the US, better understanding of risk and protective factors is important for designing intervention programs. This study provided objective measurements of physical activity to better examine the relationship between recommended levels of activity and overweight status for adolescents aged 10-14 years.

Methods

Overview: A cross-sectional analysis was conducted using baseline data from the ADOLPA study, a cohort-sequential study of the social and environmental influences on physical activity in 371 adolescents in Portland, OR from 1999-2007. This secondary analysis was conducted to examine the relationship between physical activity and the risk of overweight or obese status in adolescence.

Subject selection and data collection

Subject recruitment: Data for this study were collected from youth residing in a metropolitan area in the Pacific Northwest. Baseline data were collected from August 1999 to October 2000. As part of a longitudinal cohort-sequential study design, data were collected from three age cohorts (ages 10, 12, and 14). Families having eligible children were randomly recruited primarily using a computer-aided telephone interviewing system from 58 neighborhoods which were identified by neighborhood association classifications for North, Northeast, and Southeast Portland, OR. For a few smaller neighborhoods, door to door recruitment was also undertaken. Recruitment was balanced across seasons. Of eligible families, approximately 68% agreed to participate (S. C. Duncan, Strycker, Duncan, & Chaumeton, 2004). Compared to 2000 Census data, families in this study were representative of the county from which they were recruited in terms of race (76% of study participants vs. 79% of county residents white) and family structure (23% vs. 20.3% single-parent families).

Assessments: Participants were assessed at their homes, with two visits by project staff. At the initial visit, participants were weighed and measured and instructed on using the pedometer. One week later, the youth and a parent completed surveys in the presence of trained research assistants. The survey was administered to 10 year old children as an interview, and this option was available to all participants. Participants completed individual surveys in private, away from other family members, to enhance confidentiality. For 7 days prior to the survey, youth completed a daily record of physical activities and wore a pedometer to record the number of steps taken each day.

Participant Incentives: In Year 1, youth were paid $25 for completing the assessments with a bonus of $5 if all aspects of the assessment were completed. Parents were paid $15.

Inclusion criteria: Adolescents were included in the present study if they met the inclusion criteria for the ADOLPA study of residing in the study neighborhoods and were age 10, 12 or 14 at the time of the assessment. Participants were excluded from the present analysis if they had insufficient data to calculate a body mass index, if they did not complete pedometer recordings for at least 4 out of the 7 days, or had biologically implausible values for height, weight or mean steps per day.

Measurement of predictor variables

Pedometer. Pedometers have been shown to be valid and reliable tools for measuring youth physical activity (Rowlands & Eston, 2005; Strycker et al., 2007). At the initial assessment visit 7 days prior to the survey, youth were instructed on how to wear a pedometer and record the number of steps taken each day for 7 days. Participants were instructed to clip the pedometer to the waistline above the right knee each morning, to wear the pedometer all day while doing usual activities, and to remove the pedometer and record the day's steps at night before resetting the device and going to bed. The Yamax Digiwalker SW-701 (Optimal Health Products and Services, San Antonio, TX) was chosen for this study as it performed best in a study compared to other pedometers (Crouter, Schneider, Karabulut, & Bassett, 2003). Compliance in filling out the 7-day physical activity record was generally very good, with 99% of participants recording the daily pedometer total for at least 4 of the 7 days (70.3% completed all 7 days). The study protocol was designed to maximize use of the pedometer and recording of the data on a daily record. Along with a pedometer, youth received two project-logo magnets and were instructed to put the form on the refrigerator or in some other prominent place. Parents were encouraged to help remind children to record daily pedometer readings, and reminder phone calls were made to the family 2 days after the first visit to assure compliance with the protocol. A mean steps per day variable was computed by summing the number of steps for the week and dividing by the number of days recorded.

Physical activity levels: No clear guidelines have been established for step counts for adolescents to meet the American Academy of Pediatrics' recommendation of 60 minutes a day of moderate to vigorous physical activity. Rowlands et al assessed the relationship between pedometer counts and attainment of at least 60 minutes of moderate activity in thirty-four 8-10 year old children wearing both a Tritrac accelerometer and a Yamax pedometer. Girls accumulating 12,000 steps per day and boys with 13,000 steps per day attained 60 or more minutes of moderate activity; however, 15% of girls and 23% of boys engaged in more than 60 minutes of activity but did not meet the pedometer threshold (Rowlands & Eston, 2005). Therefore, 12,000 steps per day for girls and 13,000 steps per day for boys is a conservative goal set for children slightly younger than those in the present study. For adults, 10,000 steps per day is considered an appropriate goal for active healthy adults, and may be appropriate for older adolescents (Tudor-Locke et al., 2008). Based on the prior research, physical activity as measured by pedometer was divided into three levels for the current study. Low activity was defined as a mean of less than 10,000 steps per day. Moderate activity was defined as a mean of at least 10,000 steps per day and less than 12,000 steps for girls or 13,000 steps for boys. High activity level was defined using the Rowlands' standard of a mean of a least 12,000 steps per day for girls and 13,000 steps per day for boys.

Survey items. Three survey items were used based on prior measures (Heath, Pate, & Pratt, 1993; Sallis et al., 1993). The first two items were based on questions from the Youth Risk Behavior Survey (YRBS) (Brener et al., 2004; Heath et al., 1993; Heath, Pratt, Warren, & Kann, 1994). Youth were asked (a) "On how many of the past 7 days did you exercise or take part in hard physical activities that made you sweat and breathe hard for at least 20 min without stopping (such as basketball, jogging, swimming laps, fast bicycling, or similar aerobic activities)?" and (b) "In a typical week, how many days do you take part in any regular physical activity long enough to work up a sweat (heart beats rapidly)?" For both items, responses ranged from 0 to 7 days. The third survey item asked, "Compared to others the same age and sex, how much physical activity do you get?" (1 = *much less than others*; 5 = *much more than others*). This item was taken from a study of physical activity self-reports among children aged 10 to 16 years (Sallis et al., 1993), in which it was found to be valid and reliable (test–retest r = .93) in this age group.

Measurement of outcome variables

Body Mass Index (BMI): Overweight status, the main outcome in the present study, was measured using body mass index, and was defined as BMI ≥85th percentile for age, which includes children categorized as overweight (≥85th percentile for age) and obese (≥95th percentile for age). Trained assessors measured height (m) and weight (kg) of participants using calibrated, sensitive scales. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). BMI was plotted on sex-specific Centers for Disease Control and Prevention (CDC) growth charts for BMI to determine BMI-for-age percentile for the child's age cohort plus 6 months (10.5 years, 12.5 years, or 14.5 years)(Ogden et al., 2002). . BMI-for-age percentiles were divided into two categories based on CDC and AAP guidelines: normal weight (<85th percentile for age) and overweight (≥85th percentile for age).

Measurement of Covariates

Confounding: Other factors that are associated with childhood and adolescent obesity could potentially confound the relationship between physical activity and obesity if they are also associated with physical activity and are not in the causal pathway between these two variables. Most studies evaluating the relationship between physical activity and obesity have evaluated for age, sex, and race as potential confounding factors, (Patrick et al., 2004; Sallis et al., 2000)(Eaton et al., 2008; Nader et al., 2008), as well as demographic indicators including household income and parent education level, (Nader et al., 2008; Patrick et al., 2004; Tremblay & Willms, 2003) and family structure, including single parent (Tremblay & Willms, 2003)and only child households (Reilly et al., 2005).

Sedentary behavior, particularly time spent watching television, is an important risk factor for childhood obesity and may be inversely related to time spent engaging in physical activity (Eisenmann et al., 2008; Harrison, Burns, McGuinness, Heslin, & Murphy, 2006; Must et al., 2007; Patrick et al., 2004). The availability of neighborhood resources for physical activity is also an important potential confounder in the relationship between physical activity and overweight status.(Anderson & Butcher, 2006; Bell, Wilson, & Liu, 2008; Brownson, Boehmer, & Luke, 2005). Finally, dietary factors such as increased portion sizes and high fat diets are thought to play a large role in the childhood obesity epidemic (Hill & Peters, 1998; Patrick et al., 2004).

In the present study, the following variables were assessed for potential confounding effect on the relationship between physical activity and overweight status: age, sex, race, household income, parent education level, single parent household, only child household, television viewing time, screen time, access to parks and playgrounds, and dietary measures of fat and fiber.

Effect modification: The association between physical activity and overweight status may differ according to different strata of variables that act as effect modifiers. In the present study, age, sex, race and television were explored for potential interaction with physical activity in the relationship with overweight status.

Measures: Data on age, sex and race were available from the youth questionnaire. Age was defined as the age in years at the time of completion of the survey. Due to small sample sizes of racial and ethnic minorities, racial and ethnic background was collapsed to a two level variable of white (76.4%) and non-white (23.6%).

Social and economic status factors were available from the parent survey. Household income was defined as a two level categorical variable of less than or greater than or equal to $50,000 per year, which was the median income for Portland, OR in 2000 as well as the median income for the study sample. Parent education level was defined with four levels: less than high school, high school or equivalent (high school diploma, GED, or vocational training), some college (1-3 years of college), or college graduate or higher (college graduate or graduate/professional degree). Family structure was defined as two parent (married or living with a partner) or single parent household (separated, divorced, widowed, single-not involved in an intimate relationship and not living with partner, single- involved in an intimate relationship and not living with partner). Presence of siblings was assessed by the household survey question on number of children living in the home, and households were defined as single child vs. more than one child households.

Television viewing and screen time was assessed on the youth survey by the question, “In a typical week, how many hours a day do you spend: Watching TV, Playing video games, On the computer (not doing schoolwork),” with responses ranging from 0 to 7 or more hours for each. Based on the American Academy of Pediatrics (AAP) guidelines that children and adolescents should spend no more than 2 hours a day watching quality media programming(American Academy of Pediatrics. Committee on Public Education, 2001), television viewing time was defined as low: 0-1 hour a day, moderate: 2-3 hours a day, or high: 4 or more hours a day. A screen time variable was created by summing hours per day of television, videogames, and computer use not for schoolwork. This variable was then categorized into the same levels as the television variable of low (0-1 hour/day), moderate (2-3 hours/day), or high (4 or more hours/day).

Access to neighborhood physical activity resources was assessed on the youth survey by the question “There are playgrounds, parks, or gyms close to my home, or that my family can get to easily” with responses on a five-level Likert scale of “Strongly disagree, somewhat disagree, I am not sure, somewhat agree, strongly agree.”

Diet was assessed with the use of the Block Rapid Food Screener questionnaire on the youth survey. This 22 item food screener is comprised of 15 items designed to measure dietary fats and 7 items designed to measure fruit and vegetable intake over the past month, resulting in a score for fat intake and a score for fiber intake (G. Block, Clifford, Naughton, Henderson, & and McAdams, 1989; G. Block, Gillespie, Rosenbaum, & Jenson, 2000).

Data Analysis

Specific Aim #1: Prevalence estimates: The prevalence of adolescents defined as overweight ($\geq 85^{th}$ percentile - $<95^{th}$ percentile BMI-for-age) and obese ($\geq 95^{th}$ percentile BMI-for age) was estimated from the sample for each age and sex category. The prevalence of adolescents meeting each level of physical activity was also estimated for each age and gender. Differences in prevalence among categories were compared using Pearson’s chi-square test. These prevalence estimates were compared to YRBS and NHANES results for both Oregon and the US for 1999, which corresponds closely to the time period of the data collection for the present study. Quantitative comparisons were made using the one sample test of proportion with YRBS or NHANES data as population estimates.

Specific Aim #2: Correlation between self report of physical activity and pedometer recordings: Comparing the self report items pertaining to physical activity with the pedometer measures assessed during the same calendar period provides valuable information about the reliability of self report data. Three survey items measuring self report of physical activity were compared individually to mean steps per day on pedometer recordings using Spearman correlation to determine if there is a linear relationship between increased self report of physical activity and increased pedometer recordings. Spearman correlation was used to assess the association between the ordinal self report data with the continuous pedometer data. Correlation strength was assessed with the following criteria: 0 no correlation, 0.1-0.3 weak, 0.4-0.6 moderate, 0.7-0.9 strong, 1.0 perfect (Dancey & Reidy, 2004).

Specific Aim #3: Model building: Descriptive graphical and statistical analyses were conducted for each variable, as well as assessment for potential outliers and possible data errors. Characteristics of adolescents in the normal and overweight categories were compared using Pearson's Chi-squared tests or independent sample t-tests. Similarly, characteristics of adolescents in each physical activity category were compared to see if these teens differed with respect to demographic factors or other risk factors for overweight status.

Simple logistic regression models were used to calculate crude odds ratios with 95% confidence intervals for the risk of overweight status for adolescents in the physical activity categories, using low activity (< 10,000 mean steps per day) as the referent group.

The following variables were assessed for potential confounding or effect modification: age (10, 12, or 14), sex, race (white or non-white), household income (< or ≥ $50,000 per year), parent's education level (less than high school, high school or equivalent, some college, or college graduate or higher), family structure (single parent or two parent household), siblings (only child or sibling household), television viewing time and screen time (0-1 hour/day, 2-3 hours/day, or 4 or more hours/day), neighborhood availability of parks (1-5 Likert scale), and fat and fiber dietary scores. Categories of variables were developed based on the distribution of the data and appropriateness of cut points.

A multiple logistic regression model was built to evaluate whether physical activity was independently associated with overweight status when adjusted for other potential confounding variables. Variables were included in the initial model based on Hosmer and Lemeshow criteria for selecting variables: those with $p<0.25$ in univariate analysis, known biologic or other importance in the model, or variables that are known or suspected confounders (Hosmer & Lemeshow, 2000). Univariate analyses were conducted to assess the relationship of each variable with risk of overweight status using Pearson's Chi-squared and Student's t-tests. Variables were assessed for collinearity using Spearman's correlation, with variables considered collinear if they were strongly correlated with $r>0.6$ (Dancey & Reidy, 2004). Collinear variables were assessed for univariate significance; variables with lower univariate p values or known biologic significance were considered for inclusion.

Variables were chosen to remain in the main effects model if the p value for the individual coefficient was significant at the $p < 0.05$ level based on Wald statistic, removing non-significant variables individually until only variables significant at the $p<0.05$ level remained. All variables that were not included in the initial multivariate model selection were subsequently added individually to the model to assess for any statistical significance ($p<0.05$).

Variables were formally evaluated for possible confounding of the relationship between physical activity and overweight status. Odds ratios and regression coefficients for the relationship between physical activity categories and overweight status, adjusted for all variables in the main effects model, were compared with and without potential confounders included in the model. A variable that altered the regression coefficient for any category of physical activity by at least 10% was considered a confounder in the relationship between physical activity and overweight.

Potential effect modifiers, including age, sex, race, and television viewing time were examined for interaction with physical activity categories. Interaction terms with $p \leq 0.10$ were entered into the initial model selection and those meeting statistical significance ($p \leq 0.05$) were chosen to remain in the model.

Assessment of model fit was conducted using the Pearson's and deviance tests of goodness of fit (Hosmer & Lemeshow, 2000). The null hypothesis that the observed and expected values are close and a P-value > 0.05 indicates a good fit. Change in Pearson's residual and change in deviance were plotted against the predicted value and the leverage value to assess for potential outliers. Any potential outliers were removed and the model was compared with and without the observation if the model coefficients changed by more than 10%.

All statistical analyses were performed using Stata/IC (version 10.0.)

Human Subjects Protections: Appropriate Institutional Review Board (IRB) approval for research with human participants was obtained by the Oregon Research Institute IRB. Informed consent (adult) and assent (youth) was obtained for all participants. All data used in the present analysis was de-identified by Oregon Research Institute prior to analysis. The protocol for the present study was reviewed by the IRB at Oregon Health and Science University and authority was waived as non-human subjects analysis (OHSU IRB number 00005174).

Results

Participant Demographics: Data included 371 youth, with 50.1% of the sample being female, and 76% White, 12% African American, 4% Hispanic, 2% Asian, 2% American Indian, and 4% other or mixed races. The sample included 32.3% 10 year olds, 33.9% 12 year olds and 33.7% 14 year olds. The annual household income for the sample was: 19% under $30,000; 30%, $30,000 to $49,999; 26%, $50,000 to $69,999; 13%, $70,000 to $89,999; and 12%, $90,000 and above. Of the original sample of 371 youth, 6 individuals were excluded for missing information on the main predictor of steps per day (n = 4 individuals) or the main outcome of BMI (n= 2 individuals). The final sample size was 365 individuals. Too few individuals were excluded for formal comparisons between included and excluded subjects; however, characteristics of included and excluded adolescents were similar.

The characteristics of adolescents according to normal weight or overweight status are presented in **Table 1**. 202 youth were normal weight (BMI < 85^{th} percentile-for-age) and 163 were overweight (BMI ≥ 85^{th} percentile-for-age). The normal weight category included 7 individuals considered underweight with BMI for age percentile less than 5 percent. Too few underweight individuals were present for formal comparisons with normal weight youth; however characteristics of normal and underweight youth were similar. Excluding these 7 subjects did not significantly change any results, so these youth were included in the final analysis. Overweight adolescents were different from normal weight adolescents in terms of higher television viewing time, higher screen time and lower household income (**Table 1)**. **Table 2** presents characteristics of adolescents according to physical activity level. Overall, 188 adolescents (51%) had the lowest level of physical activity, a mean of less than 10,000 steps per day. 79 adolescents (22%) reached the moderate level of 10,000- 12,000 steps per day for girls and 10,000- 13,000 steps per day for boys, while 98 adolescents (27%) achieved the highest level with at least 12,000 steps per day for girls and 13,000 steps per day for boys. Also, more boys achieved higher activity levels, and television viewing and screen time were lower in those achieving high physical activity.

Table 1. Baseline characteristics according to normal or overweight/obese status in the Adolescent Physical Activity (ADOLPA) Study of adolescents in Portland, OR, 1999-2000

Characteristic	Normal Weight[a] (n=202)		Overweight and Obese [b] (n=163)		Comparison Normal vs. Overweight
	n	Mean(SD) or %	n	Mean(SD) or %	P value
Physical Activity level[c]					**<0.001†**
Low	87	43.1	101	62.0	
Mid	46	22.8	33	20.2	
High	69	34.2	29	17.8	
Age, y					0.896†
10	66	32.7	52	31.9	
12	70	34.6	54	33.1	
14	66	32.7	57	35.0	
Sex					0.446†
Female	106	52.5	79	48.57	
Male	96	47.5	4	51.5	
Time watching TV(hrs)	203	2.45(1.82)	166	6.0(1.41)	**0.007‡**
0-1 hr/day	75	37.1	36	22.1	**0.007†**
2-3 hrs/day	77	38.1	74	45.4	
4+ hrs a day	50	24.8	53	32.5	
Screentime[d]					**0.007†**
0-1 hr/day	25	12.5	11	6.8	
2-3 hrs/day	69	34.5	39	24.1	
4+ hrs/day	106	53.0	112	69.1	
Family Structure					0.078†
Single-parent house hold	40	19.9	45	27.8	
Two-parent house hold	161	80.1	117	72.2	
Siblings					0.17†
Single-child household	22	10.8	26	15.7	
Sibling-household	181	89.2	140	84.3	

Characteristic	Normal Weight (n=202)		Overweight and Obese (n=163)		Comparison Normal vs. Overweight
	n	Mean(SD) or %	n	Mean(SD) or %	P value
Race					0.060†
Non-white	40	19.8	46	28.2	
White	162	80.2	117	71.8	
Race/Ethnicity					0.122†
White	162	80.2	117	71.8	
Black	21	10.4	20	12.3	
Native American	1	0.5	5	3.1	
Hispanic	5	2.5	11	6.8	
Asian	5	2.5	3	1.8	
Other/mixed race	8	3.9	7	4.3	
Parent Education Level					0.301†
Less than High School	7	3.5	8	4.8	
High School or Equivalent	42	20.8	48	28.9	
Some College	59	29.2	45	27.1	
College Grad or Higher	94	46.5	65	38.1	
Household Income					**0.025**†
≥$49,999	88	44.0	90	55.9	
$50,000 or more	112	56.0	71	44.1	
Availability of Parks					0.654†
Less available	30	14.9	27	16.6	
More available	172	85.1	136	83.4	
Fat intake	202	32.75(1.68)	163	32.68(190)	0.977‡
Fiber intake	202	31.1(0.55)	163	31.4(0.59)	0.714‡

Bold $p<0.05$, † chi-squared test, ‡ Student's t-test

[a]Normal Weight: < 85th percentile BMI-for-age

[b]Overweight and Obese: ≥ 85th percentile BMI-for-age

[c] Physical activity levels: Low(less than 10,000 steps per day), Mid (10,000-<12,000 steps per day for girls, 10,000-<13,000 steps per day for boys) High (≥12,000 steps/day for girls, ≥13,000 steps/day for boys)

[d]Screentime = time spent watching TV+ videogames + computers not for schoolwork

Table 2 Baseline characteristics according to level of physical activity in the Adolescent Physical Activity (ADOLPA) Study of children in Portland, Oregon, 1999-2000

Characteristic	Total	Physical Activity Level [a] Low (n=188)		Moderate (n=79)		High (n=98)		Comparison
	N	n	% or mean(SD)	n	% or mean(SD)	n	% or mean(SD)	P value
Age, y	365							0.226[†]
10		64	34.0	27	34.2	27	27.5	
12		70	37.2	21	26.6	33	33.7	
14		54	28.7	31	39.2	38	38.8	
Sex	365							**<0.001[†]**
Female		113	60.1	28	35.4	44	44.9	
Male		75	39.9	51	64.6	54	55.1	
BMI[b]	365							**<0.001[†]**
Normal weight		87	46.3	46	58.2	69	70.4	
Overweight or Obese		101	53.7	33	41.8	29	29.6	
Time watching TV, hrs	365							**0.017[†]**
0-1 hrs		42	22.3	31	39.2	38	38.7	
2-3 hrs		88	46.8	28	35.4	35	35.7	
4 + hrs		58	30.9	20	25.3	25	25.6	
Screentime[c], hrs	362							**0.041[†]**
0-1 hr		13	7.0	13	16.9	10	10.2	
2-3 hrs		50	26.7	27	35.1	31	31.6	
4+ hrs		124	66.3	37	48.0	57	58.2	
Family Structure	363							0.254[†]
Single-parent household		47	25.1	13	16.5	25	25.8	
Two-parent household		140	74.9	66	83.5	72	74.2	
Siblings	365							0.906[†]
Single-child household		25	13.3	9	11.4	13	13.3	
Sibling-household		163	86.7	70	88.6	85	86.7	

Characteristic	Physical Activity Level							
	Total	Low (n=188)		Moderate (n=79)		High (n=98)		Comparison
	N	n	%	n	%	n	%	P value
Race/Ethnicity	365							0.303†
White		139	73.9	66	83.5	74	75.5	
Black		22	11.7	6	7.6	13	13.3	
Native American		3	1.6	3	3.8	0	0	
Hispanic		12	6.4	0	0	4	4.1	
Asian		4	2.1	1	1.3	3	3.1	
Other/Mixed race		8	4.3	3	3.8	4	4.1	
Parent Education Level	364							0.524†
Less than High School		4	2.2	5	6.3	6	6.2	
High School or Equiv.		46	24.5	17	21.5	25	25.8	
Some College		58	30.8	21	26.6	24	24.7	
College Grad or above		80	42.5	36	45.6	42	43.3	
Household Income	365							0.290†
$49,999 or less		92	49.5	43	55.8	43	44.9	
$50,000 or more		94	50.5	34	44.2	55	56.1	
Availability of Parks	365							0.450†
Less Available		25	13.3	14	17.7	18	18.4	
More Available		163	86.7	65	82.3	80	81.6	
Fat Intake	365	188	31.7(22.1)	79	32.6(26.9)	98	34.8(25.4)	0.592€
Fiber Intake	365	188	31.6(7.8)	79	29.8(7.5)	98	31.9(7.8)	0.143€

Bold p<0.05, † chi-squared test, ‡ Student's t-test € ANOVA

[a] Physical activity levels: Low(less than 10,000 steps per day), Mid (10,000-<12,000 for girls, 10,000-<13,000 steps per day for boys) High (≥12,000 steps/day for girls, ≥13,000 steps/day for boys)

[b]Normal Weight (<85th percentile for age) Overweight and Obese (≥ 85th percentile for age)

[c]Screentime = time spent watching TV+ videogames + computers

Specific Aim #1. Prevalence of overweight and obese status and levels of physical activity

Overall, 44.7% of the sample was classified as overweight, defined as BMI-for-age-percentile ≥85th percentile. There was no significant difference in the proportion of girls (42.7%) and boys (46.6%) of overweight (p = 0.446).The proportions of overweight were also not significantly different among the three age groups, with 44.1% for 10 yr olds , 43.5% for 12 year olds and 46.3% for 14 yr olds (p=0.896). Twenty three percent of the entire sample was classified as obese (BMI-for-age percentile ≥ 95th percentile), with 22.7% of girls and 23.9% of boys obese (p= 0.718). There was no significant difference in the proportion of obese youth by age, with 22.0% of 10 yr olds, 22.6% of 12 year olds, and 25.2% of 14 yr olds obese (p=0.822). The prevalence of overweight and obese status by age and sex is presented in **Table 3**.

Table 3. Prevalence of overweight and obesity and physical activity by age and sex among adolescents in Portland, OR 1999-2000 (n=365)

Characteristic	**Girls n (%)**			**p-value**	**Boys n (%)**			**p-value**
	10yr	**12yr**	**14yr**		**10yr**	**12yr**	**14yr**	
BMI								
Normal Weight [a]	39(62.9)	35(56.5)	32(52.5)	0.497	27(48.2)	35(56.5)	34(54.8)	0.641
Overweight and Obese [b]	23(37.1)	27(43.5)	29(47.5)		29(51.8)	27(43.5)	28(45.2)	
Non Obese[c]	50(82.0)	47(72.8)	45(73.8)	0.501	41(73.2)	49(79.0)	47(75.8)	0.759
Obese [d]	11(18.0)	15(24.2)	16(26.2)		15(26.8)	13(21.0)	15(24.2)	
Physical Activity Level								
Low [d]	37(59.7)	43(69.3)	33(54.1)	0.536	27(48.2)	27(43.5)	21(33.8)	0.323
Moderate [e]	10(16.1)	7(11.3)	11(18.0)		17(30.4)	14(22.6)	20(32.3)	
High [f]	15(24.2)	12(19.4)	17(27.9)		12(21.4)	21(33.9)	21(33.9)	

[a] BMI for age < 85th percentile
[b] BMI for age ≥ 85th percentile
[c] BMI for age < 95th percentile
[d] BMI for age ≥ 95th percentile
[d] Less than 10,000 steps per day
[e] 10,000-< 12,000 for girls, 10,000-<13,000 steps per day for boys
[f] Greater than or equal to 12,000 steps/day for girls, ≥13,000 steps/day for boys

The proportion of overweight and obese adolescents in this sample was compared to prevalence estimates from larger survey data from 1999-2000, the same time period as the data collected for the present study. Adolescents in the present study were significantly more likely to be overweight (44.7%) than the population estimates from the 1999 Oregon YRBS which estimated that 18% were overweight ($p<0.0001$), and the 1999 National YRBS which found that 26% were overweight ($p<0.0001$). The prevalence of overweight in this study was also significantly different from the 1999 NHANES estimate of 30.4% of adolescents overweight ($p <0.0001$). These comparisons are presented in **Table 4.**

Table 4. Comparison of prevalence of overweight and obese adolescents in the ADOLPA study with YRBS and NHANES studies, 1999-2000.

	ADOLPA	1999 Oregon YRBS		1999 US YRBS		1999 NHANES	
Percent Overweight[a]	44.7	18.0	p< 0.0001	26.0	p<0.0001	30.4	p<0.0001
Percent Obese[b]	23.0	6.0	p<0.0001	15.0	p<0.0001	15.5	p<0.0001

[a]BMI for age ≥ 85^{th} percentile

[b] BMI for age ≥ 95^{th} percentile

The prevalence of adolescents meeting physical activity standards was estimated for each physical activity category. Fifty one percent of all study participants had the lowest level of physical activity, with 21.6% attaining the moderate level, and 26.9% achieving the highest level of activity. Girls were significantly more likely to be in the lowest physical activity level compared to boys (61.1% vs. 41.7%, $p<0.001$). Physical activity levels did not differ significantly by age ($p=0.226$). The prevalence of youth meeting physical activity levels by age and sex is presented in **Table 3**. The prevalence of adolescents in the present study meeting the highest level of activity was significantly different from the 2007 national YRBS estimate that 34.7 percent of adolescents were active for 60 minutes per day ($p= 0.001$). The percent of girls achieving 60 minutes a day of activity was not significantly different between studies ($p=.28$); however boys in the present study were less likely to achieve this level than boys in the 2007 national YRBS ($p=0.0001$).

Specific Aim #2. Correlation between self report of physical activity and pedometer recordings

Correlations between mean steps per day as recorded by pedometer and self report physical activity measures were weak but statistically significant for all three questionnaire measures. **Table 5** presents the Spearman correlation coefficients for the three comparisons.

Table 5. Correlations between responses to self report physical activity survey questions and physical activity as measured by mean steps per day by pedometer.

Self report physical activity measure	Spearman's Correlation Coefficient	Strength of correlation	p-value
Vigorous physical activity[a]	0.2474	weak	<0.0001
Regular physical activity[b]	0.2489	weak	<0.0001
Physical activity compared to others[c]	0.2407	weak	<0.0001

[a] On how many of the past 7 days did you exercise or take part in hard physical activities that made you sweat and breathe hard for at least 20 min without stopping (such as basketball, jogging, swimming laps, fast bicycling, or similar aerobic activities)?

[b] In a typical week, how many days do you take part in any regular physical activity long enough to work up a sweat (heart beats rapidly)?

[c]Compared to others the same age and sex, how much physical activity do you get?

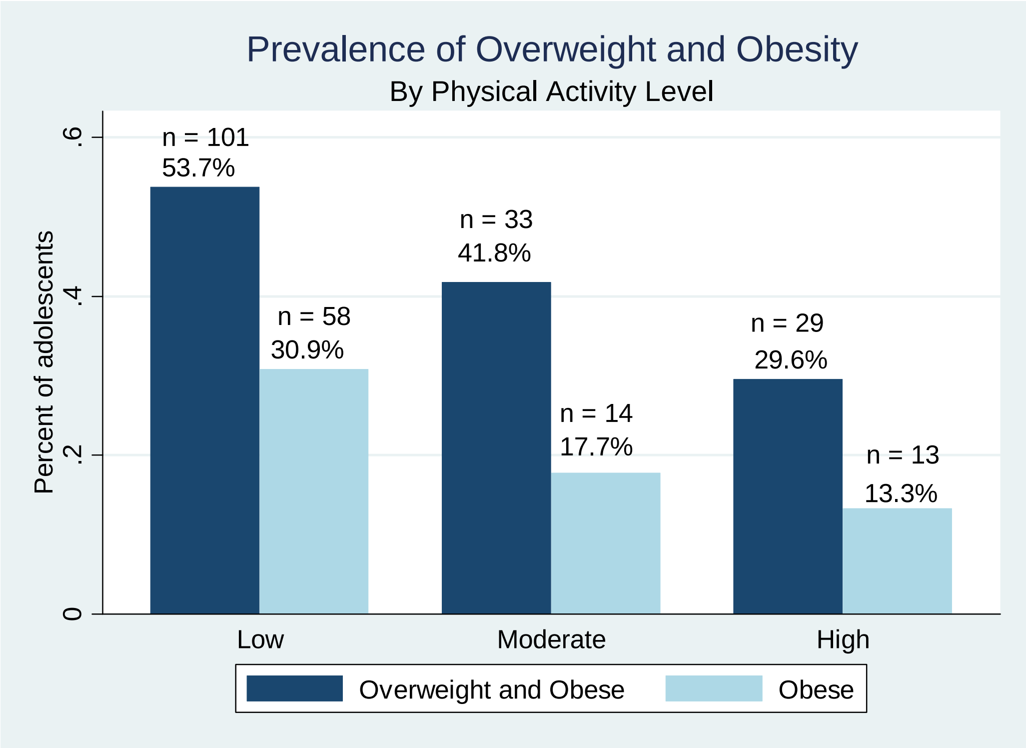
In addition, when looking at bivariate association between the self-reported physical activity measures and overweight, only the self-reported amount of physical activity compared to others was associated with overweight status. Those who reported more or much more exercise than others of their same age and sex had 38% lower odds of overweight status than those reporting less or much less exercise than their peers (OR 0.62, 95% CI 0.45, 0.85, p= 0.003). The questions on vigorous activity over the past week and regular physical activity in a typical week were not associated with overweight status.

Specific Aim #3. Analysis of the relationship between physical activity and overweight status, adjusting for potential confounders.

Univariate analysis

The risk of overweight status was greatest for those adolescents in the lowest physical activity category and inversely associated with increased physical activity levels (**Figure 1, Table 6**). The highest level of physical activity was protective against overweight, with the crude odds of overweight 64% lower than those in the lowest physical activity level (Crude OR 0.36, 95% CI 0.22 - 0.61. p< 0.001). Those adolescents in the moderate physical activity category were less likely to be overweight than those in the lowest category, although the association was not significant (Crude OR 0.62, 95% CI 0.36-1.05, p=0.076). The Mantel -Haenzsel test for trend demonstrated a linear trend towards lower prevalence of overweight with increasing levels of physical activity (p<0.001). Similarly, with physical activity as a 3 level continuous variable, the odds of overweight decreased by 40% for each increase in activity level (Crude OR 0.60; 95% CI 0.47, 0.78, p< 0.001).

Figure 1. Prevalence of overweight and obesity by physical activity level among adolescents in Portland OR, 1999-2000



[a]Physical activity levels: Low(less than 10,000 steps per day), Mid (10,000-<12,000 steps per day for girls, 10,000-<13,000 steps per day for boys) High (> 12,000 steps/day for girls, >13,000 steps/day for boys)

Overweight: ≥ 85[th] percentile BMI-for-age

Obese: ≥ 95[th] percentile BMI-for-age

Sedentary behavior was also associated with risk of overweight status (see **Table 6).** The risk of overweight was lowest for adolescents in the lowest television viewing category and increased significantly with higher levels of viewing time, with the odds of overweight at least double for those watching two or more hours of television a day compared to those watching less than two hours. The relationship was similar for increasing levels of screen time.

Table 6. Crude odds of overweight (≥85th percentile BMI-for-age) for levels of physical activity and sedentary behavior for adolescents in the ADOLPA study in Portland, OR, 1999-2000.

Characteristic	OR (95% CI)	P-value
Physical activity level[a]		**<0.001** overall
Low	**1.0**	---
Moderate	**0.62 (0.36, 1.05)**	0.076
High	**0.36 (0.22, 0.61)**	**<0.001**
TV time		**0.007** overall
Low: 0-1 Hr/day	**1.0**	---
Mid: 2-3 hrs/day	**2.0 (1.2, 3.3)**	**0.008**
High: 4+ hrs/day	**2.2(1.3, 3.8)**	**0.005**
Screen time[b]		**0.006** overall
Low: 0-1 hr/day	**1.0**	---
Mid: 2-3 hrs/day	**1.3 (0.6, 2.9)**	0.545
High: 4+ hrs/day	**2.4 (1.1, 5.1)**	**0.023**

[a] Physical activity levels: Low(less than 10,000 steps per day), Mid (10,000-12,000 steps per day for girls, 10,000-13,000 steps per day for boys) High (≥12,000 steps/day for girls, ≥13,000 steps/day for boys)

[b] Screentime = time spent watching TV+ videogames + computers not for schoolwork

Multivariate analysis

Based on Hosmer and Lemeshow criteria for variable selection, the following variables were included for initial model selection with univariate p values < 0.25: television, screen time, household income, race, parent education level, family structure and siblings. Additionally, age and sex were included for their potential biologic significance. Television and screen time were collinear with Spearman's rho = 0.676. With the sum of television, videogames and computer time, the screen time variable was highly skewed to the right with only 9.9 percent of individuals in the lowest level and 60.2 percent in the highest. In contrast, the distribution of the television variable allowed enough individuals in each level. The screen time variable could also be biased to overestimate screen time if youth are multitasking, and may also be less accurate as a combination of three subjective time estimations. Therefore, since television was the major contributor to the variability in screen time, and was felt to be a more accurate variable compared to the composite variable of screen time; television remained in the model while screen time was dropped. No other variables exhibited significant collinearity.

In an adjusted multivariate model, physical activity level, television viewing time, and household income were associated with the risk of overweight status. Since sex was significantly associated with physical activity, it was included as a potential confounding variable. Sex had a small negative confounding effect on the relationship between physical activity and overweight status. When sex was removed from the model, the adjusted OR was reduced by 8% for those adolescents in the moderate physical activity category (OR_{adj} 0.644) and 5% for those in the highest physical activity category (OR_{adj} 0.382), comparing to the lowest activity level.

The addition of age and race to the multivariate model changed the measure of effect between physical activity and overweight status less than 5% for any physical activity category, so age and race were not included as confounding variables.

Previous research and stratified analyses indicated that age, sex, race and television viewing might modify the relationship between physical activity and overweight status (Eisenmann et al., 2008; Nader et al., 2008; Ogden et al., 2008; Patrick et al., 2004). Two-way interaction terms of these variables and physical activity level were added individually to the model. None of the interaction terms was statistically significant at the p = 0.10 level.

The final multivariate model describing the risk of overweight status included physical activity level, television viewing time, household income and sex. The adjusted odds ratios and 95% confidence intervals describing the risk of overweight among adolescents in each physical activity category are presented in **Table 7**.

Table 7. Adjusted Odds of Overweight (≥85th percentile BMI-for-age) for levels of physical activity and sedentary behavior for adolescents in the ADOLPA study in Portland, OR 1999-2000.

Characteristic	OR(95% CI)	P-value
Physical activity level[a,b]		**<0.001** overall
Low	1.0	---
Mid	0.64 (0.37, 1.1)	0.128
High	0.38 (0.22, 0.66)	**<0.001**
Television viewing time[c]		**0.048**
Low: 0-1 Hr/day	1.0	---
Mid: 2-3 hrs/day	1.7 (1.02, 2.9)	**0.043**
High: 4+ hrs/day	2.2 (1.01, 3.2)	**0.048**
Household income[d]		**0.045**
Less than $50,000/yr	1.0	
≥ $50,000/yr	0.64 (0.42, 0.99)	
Sex[e]		0.227
Girls	1.0	
Boys	1.3 (0.84, 2.1)	

[a] Physical activity levels: Low(less than 10,000 steps per day), Mid (10,000-<12,000 steps per day for girls, 10,000-<13,000 steps per day for boys) High (≥12,000 steps/day for girls, ≥13,000 steps/day for boys)

[b]Adjusted for television viewing time, household income and sex

[c]Adjusted for physical activity, household income and sex

[d]Adjusted for physical activity, television viewing time and sex

[e]Adjusted for physical activity, television viewing time and household income

After adjusting for television time, income and sex, physical activity was significantly associated with overweight status (p= 0.0002). The odds of overweight were 62% lower for those adolescents in the highest physical activity category compared to the lowest level of physical activity (OR_{adj} 0.38 (95% CI, 0.22, 0.66), p< 0.001). There was a non-significant trend showing that moderate physical activity was also protective, with 36% lower odds of overweight (OR_{adj}

0.64 (95% CI, 0.37, 1.1), p =0.128). When physical activity was considered as a 3 level continuous variable, the trend was significant with 38% lower odds of overweight with each increase in physical activity level (OR_{adj} 0.62 (95% CI, 0.48, 0.81), p< 0.001).

In addition, the odds of overweight were 70% higher for adolescents who watched 2-3 hours of television per day (OR_{adj} 1.7 (95% CI, 1.02, 2.9), p =0.043) and more than doubled for those watching 4 or more hours of television per day (OR_{adj} 2.2 (95% CI, 1.01, 3.2), p = 0.048). Higher income had a protective effect, with those in families earning at or above the median income of $50,000 per year having 36% lower odds of overweight than those in families earning less than $50,000 per year ($OR_{adj}$ 0.64 (95% CI, 0.42, 0.99), p=0.045). The overall model was statistically significant (LR χ^2 (6) = 26.66, p = 0.0002).

Assessment of model fit and discriminative ability

Change in Pearson's residual, change in deviance and Cook's distance were plotted against the predicted value and the leverage value to assess for potential outliers. No values were out of range; however 6 observations with change in Pearson's greater than 5.0 and change in deviance greater than 7.0 were reevaluated. Removal of these observations did not change the odds ratios by more than 10% and did not alter the conclusion, so the original, more conservative model was retained. The full model demonstrated goodness of fit by the Pearson test (p=0.6597) and the deviance test (p=0.495).

Discussion

Prevalence of overweight and obese status

Among 10-14 year old adolescents enrolled in the ADOLPA study in Portland OR in 1999-2000, nearly 45% were classified as overweight or obese, with BMI-for-age at or above the 85th percentile, and 23% classified as obese with BMI-for-age at or above the 95th percentile. This estimate of the prevalence of overweight and obesity is significantly higher than estimated by self report survey data. The Oregon Youth Risk Behavior Surveillance (YRBS) from the same year estimated that only 18 percent of Oregon adolescents were overweight or obese, with 6% obese (Oregon Department of Human Services, 1999). Nationally, the 1999 YRBS data estimated that 26% of adolescents were overweight or obese and 15% obese (Oregon Department of Human Services, 1999). The prevalence of overweight and obesity in the present study was significantly higher than the national and Oregon-specific YRBS studies for 1999 ($p<0.0001$**).** The NHANES survey which measured the height and weight of 8165 adolescents in 1999-2000 estimated that 30.4% of American 12-19 year olds were overweight or obese and 15.5% were obese(Ogden, Flegal, Carroll, & Johnson, 2002); however, the prevalence in the current study was also significantly higher than these estimates ($p<0.0001$). The estimates of the present study are very similar to those found by Patrick *et al* in a study of 878 adolescents in San Diego, California aged 11-15 years in which BMI was objectively measured in 2001-2002. In this study, 45.7% of the sample was classified as overweight with 47.3% of girls and 43.8% of boys with BMI over the 85th percentile , which is not significantly different than in the present study ($p=0.64$).

The higher estimates of adolescent overweight and obesity in our study are likely reflective of the inaccuracies of self-report measures for BMI. A literature review of 11 studies comparing self reported with directly measured height and weight in adolescents found that the sensitivity of self report data for classifying overweight status was only 55% to 76% , with self report data consistently underestimating overweight prevalence by up to 17.7% (Sherry, Jefferds, & Grummer-Strawn, 2007). Additionally, this review found that females and overweight individuals were more likely to underestimate their weight than males or normal weight adolescents (Sherry et al., 2007). In large surveys, missing data on height and weight can also lead to further bias. Self-reported weights were missing from 40% of 12 year olds and 25% of 13 year olds in NHANES III data from 1988-1994(Himes & Faricy, 2001). More recently, Sherry reported that missing height and weight self report data ranged from 0% to 23% in the 11 studies reviewed (Sherry et al., 2007).

The present study objectively measured BMI, with trained assessors weighing and measuring participants using calibrated scales and only 0.5% (2 of 371) of the participants had missing data on height or weight. The resulting prevalence estimates for overweight and obesity are likely more accurate than those reached by the YRBS, indicating that adolescent overweight and obesity is a larger problem in Oregon than previously recognized. As recent studies indicate that childhood and adolescent overweight and obesity prevalence has increased since 2000(Ogden et al., 2006; Ogden et al., 2008), the current prevalence is likely higher than 45%.

Prevalence of adolescents meeting physical activity levels

Among study participants, the prevalence of adolescents meeting the highest level of physical activity was 26.9%, with 30% of boys and 24% of girls reaching this level. This high level of steps per day is a proxy measurement for reaching the AAP guidelines of 60 minutes per day of moderate to vigorous physical activity (Rowlands & Eston, 2005). The 1999 YRBS survey did not ask about 60 minutes a day of activity; however, the 2007 national YRBS found that 34.7% of high school students met this level of activity, with 43.7% of males and 25.6% of female reporting 60 minutes a day of physical activity (Eaton et al., 2008). While the results are similar for female students in both studies (p= 0.28), the present study found that fewer adolescents overall (p=0.001) and fewer boys (p=0.0001) were meeting the highest level of activity than estimated by the YRBS. This discrepancy may be related to the differences in measurement of physical activity by self report versus pedometers. Youth are more likely to over report their activity level compared to objective measures such as pedometers; however, a previous study found that boys tended to be more accurate reporters than girls (Sallis et al., 1993).

Correlation between self report of physical activity and pedometer recordings

The weak correlations between self ratings of physical activity on the survey and the more objective pedometer recordings suggest that questionnaire self report measures may not be a valid measure of youth physical activity. While self report measures do not tend to be very accurate for youth, Sallis found that validity and reliability of self report measures increased with age (Sallis et al., 1993). In the present study, the correlation between the questionnaire measure on hard physical activity over the past week and mean steps per day did improve slightly for the older age groups; however the correlations were weak at all ages (r = 0.20 for 10 year olds, r =

0.23 for 12 year olds and r = 0.28 for 14 year olds). Younger children and adolescents may not have the intellectual capacity to accurately recall and judge activity levels (Sallis et al., 1993)especially over longer time periods. Estimating physical activity over a typical week may be more difficult to conceptualize than estimating over the last 7 days.

Alternatively, the low correlations may reflect an imprecise comparison. Two of the questions ask about days per week achieving physical activity hard enough to work up a sweat and breathe hard, which is a proxy for vigorous activity. However, pedometers measure all levels of activity from vigorous to low level activities of daily living. Additionally, the pedometer variable was a mean of activity over 4-7 days, while the survey measures may reflect high levels of activity on some days with lower levels on others. For the question comparing physical activity to others of the same age and sex, we would expect a correlation between higher numbers of steps and reporting higher levels of activity; however, the correlation coefficient for this measure was similarly weak.

As a measure of risk of inadequate physical activity, only the question comparing one's activity to others was found to be independently associated with overweight status. Those reporting more or much more physical activity than others their same age and sex had 38% lower odds of overweight as those who reported getting less activity than their peers. This question may be an easier conceptual method for children and adolescents to rate their activity level. Those reporting less or much less activity than their peers may be a target for obesity prevention interventions.

Physical activity and the risk of overweight status

The present study estimates the protective effect of physical activity on adolescent overweight status in a large population based sample of 10-14 year olds living in Portland, OR in 1999-2000. Fifty four percent of youth taking less than 10,000 steps a day were overweight or obese compared to 42% of youth achieving moderate levels of physical activity and 29.5% of youth meeting the goal of 12,000 steps a day for girls and 13,000 steps a day for boys (**Figure 1)**. After adjusting for television viewing, income and sex, the overall odds of overweight status were 35% lower for youth reaching at least 10,000 steps ($p = 0.13$) and 62% lower for youth reaching the highest level of activity ($p<0.001$) relative to the risk among those in the lowest physical activity level.

Previous studies of adolescent physical activity have been inconsistent in linking physical activity to overweight status in youth (Must & Tybor, 2005; Sallis et al., 2000). A large review in 2000 of the current literature found that 16 of 32 studies (52%) in children age 4-12 and 6 of 21 studies (29%) in adolescents age 13-18 found a positive association between physical activity and BMI (Sallis et al., 2000).   In a more recent review, 7 of 12 cross sectional studies in children or adolescents (58%) found that overweight youth had lower physical activity levels than normal weight youth, with 3 of the significant studies using accelerometry as an objective measure of physical activity and all others using self or parental report(Must & Tybor, 2005). Similarly, only 8 of 17 longitudinal studies showed any significant associations between activity levels and obesity (Must & Tybor, 2005). Only one study in this review used pedometers as an objective measure. In a study of 436 French youth age 8-18, non-obese at baseline, Kettaneh *et al* divided participants into low or high activity based on 7 days of pedometer data at baseline and found no differences between groups at follow-up in adiposity measures (BMI, skin fold thickness, percent body fat and waist circumference)(Kettaneh et al., 2005). Studies using accelerometry to measure physical activity have been more likely to show an association with overweight status. In a recent study of 878 11-15 year olds, Patrick *et al* found that adolescents achieving less than 60 minutes per day of moderate to vigorous physical activity by accelerometer were more likely to be overweight or obese (boys p=0.006, girls p = 0.005)(Patrick et al., 2004). This study also demonstrated that as minutes per day of vigorous physical activity increased, the risk of overweight or obesity decreased (OR = 0.93; 95% CI 0.89-0.97) (Patrick et al., 2004). In our study, achievement of higher levels physical activity as measured by pedometer was clearly linked to decreased risk of overweight for 10-14 year olds, adding significantly to the current literature. Pedometers are easier to use and significantly more affordable than accelerometers, making them a valuable research tool.

The extensive survey data available for this study allowed us to evaluate and adjust for important measured confounders. Previous studies have suggested that sex, older age, non-white race, lower socio-economic status, limited neighborhood resources, increased television and screen time, and high fat, low fiber diets are risk factors for adolescent overweight status(Eaton et al., 2008; Nader et al., 2008; Patrick et al., 2004; Sallis et al., 2000) (Bell et al., 2008; Eisenmann et al., 2008). Among these variables, increased television viewing and lower income were associated with overweight status in our data and were included in the final model. Although sex was not independently associated with overweight status in our data, it was associated with physical activity level and had a measurable confounding effect.

This study found that increased sedentary behavior as measured by television viewing time was associated with increased risk of overweight status. After adjusting for physical activity, income and sex, the odds of overweight were 70% higher for adolescents who watched 2-3 hours of television a day ($p = 0.043$) and 2.2 times higher for those who watched 4 or more hours a day ($p = 0.048$). Increased physical activity was associated with both lower risk of overweight and with lower time watching television. Only 22% of youth in the lowest level of physical activity met AAP recommendations for less than 2 hours of television a day, while 39% of youth in both the moderate and high physical activity categories met this guideline. While both greater television viewing ($p = 0.017$) and lesser physical activity ($p < 0.001$) were associated with overweight status in the present study, achieving the highest level of physical activity had a larger protective odds ratio than watching less than 2 hours of television. .

Prior studies of adolescent physical activity and overweight status have also found that television viewing is an additional risk for overweight. Patrick *et al* found that boys who were overweight or obese reported significantly more television viewing time than normal weight boys ($p < 0.001$), although no difference was seen for girls, while increased physical activity was protective for both sexes (Patrick et al., 2004). Using 1999 YRBS self report data, Eisenmann *et al* also found that increased physical activity was associated with lower BMI and with lower television viewing; however, in this study television viewing was a stronger predictor of BMI than physical activity (Eisenmann et al., 2008). This study also found a strong interaction between physical activity and television viewing such that the highest risk of overweight was found in girls with high television viewing and low vigorous physical activity (OR = 3.11)(Eisenmann et al., 2008). In contrast to the Patrick study, the associations in the Eisenmann study were stronger for girls than boys. These findings contrast with the present study as well, which did not find significant interactions between physical activity and television viewing, or significant interactions of the main predictors with sex.

Household income was also a significant predictor of overweight status after controlling for physical activity, television and sex. Youth in households earning above the median income of $50,000 per year had 36% lower odds of overweight than youth in lower income homes. In the NHANES III study from 1988-1994, there was a similar inverse relationship between overweight prevalence and family income for non-Hispanic white adolescents which was not seen for Hispanic or black youth (Troiano & Flegal, 1998). Lower income youth may have many risk factors for obesity including reduced access to physical activity resources such as sports teams or gym memberships and reduced access to nutritional foods.

Limitations

Although measurement of physical activity via pedometers is likely to be more accurate than self report measures (Strycker et al., 2007; Tudor-Locke et al., 2004), pedometers are not entirely without drawbacks.   The pedometer measures motion in the vertical axis and is very accurate for running and walking; however, it is less reliable for circular motions such as bicycling (Tudor-Locke, Williams, Reis, & Pluto, 2002). Even within walking and running, pedometers have limitations because of differences in participants' walking stride length and because one cannot determine the percent of running strides and walking strides or speed of walking. Additionally, pedometers cannot record aquatic activities such as swimming, and may not be able to be worn for contact sports (Strycker et al., 2007). The physical activity measures selected for this study were based on many factors, including the epidemiological nature of the study, the availability of measures at the time the study started, prior findings, study aims, and practicality and simplicity (S. C. Duncan et al., 2007). Because results of this study are affected by the physical activity measures, other studies with different measures may reasonably yield different results.

The above limitations of the pedometer could lead to misclassification bias that underestimates physical activity levels, especially for more active youth who are involved in bicycling, aquatic or contact sports. Another limitation to consider is that the analysis did not account for seasonal differences in physical activity, so that the 7 days of measurement may not be reflective of a teen's typical level of activity. Additionally, previous studies have demonstrated that youth tend to be less active on weekends as compared to weekdays (Nader et al., 2008). The present analysis did not account for days of the week, leading to the possibility of underestimating activity for those youth whose 4 days of monitoring included 2 weekend days. However, any underestimation by season or day of the week should be non-differential between overweight and normal weight teens.

In the Rowlands study which developed the recommendation for 12,000 steps per day for girls and 13,000 steps per day for boys, 15% of girls and 23% of boys engaged in more than 60 minutes of activity but did not meet the pedometer threshold (Rowlands & Eston, 2005). The Rowlands study was conducted with 8 to 10 year olds, while the present study involved older youth who have longer strides and may take fewer steps for same level of activity, resulting in the possibility of a larger percentage of youth who may be reaching the goal of 60 minutes of physical activity without reaching the pedometer threshold. However, any bias is likely to be non-differential between weight groups as age was not associated with weight. This potential misclassification could partially explain the lower estimates of boys in the present study reaching the highest level of physical activity compared to the YRBS data.

An additional limitation of the pedometer measurement is that the devices were unsealed so that youth recorded their daily values on a log sheet, raising the possibility of reporting bias. Inaccurate recording by accident or intention could potentially lead to an overestimation of physical activity levels. However, the low prevalence of youth reaching the highest level of activity suggests that any overestimation is not large.

The act of wearing the pedometer and recording daily physical activity could also lead to overestimations of typical levels of activity, as pedometers are known to motivate change by focusing attention and providing feedback on activity (Strycker et al., 2007). However, an analysis of the ADOLPA dataset found that step counts were consistent across 5 days of monitoring, instead of increasing throughout the week as would be expected if feedback was very influential (Strycker et al., 2007).

Despite these potential sources of bias, pedometers have been shown to be accurate and reliable measures of physical activity for youth. A review of 25 articles assessing the validity of pedometers in all age groups found that pedometers correlated strongly with accelerometers (median r =0.86) and with observations of time spent in physical activity (median r = 0.82), and were negatively correlated with time in observed inactivity (median r = -0.44) (Tudor-Locke et al., 2002). In studies of children, pedometers have also been shown to be strongly correlated with direct observation (r = .80-0.97) and with accelerometers (r =0.50-0.99) (Sirard & Pate, 2001). In another analysis of the same ADOLPA data used for the present study, reliability coefficients for the pedometer ranged from 0.73 for two days to 0.82 for five or more days of data collection (Strycker et al., 2007).

Some residual confounding is also possible in our study. Unmeasured confounding variables that are associated with both physical activity and overweight status may be affecting this relationship. This study did not measure any genetic or health factors which may be related to both inadequate activity and weight. Unknown factors associated with weight and activity that have yet to be elucidated may also be involved.

Additionally, measurement error of the covariates could lead to inaccuracies in our characterization of the relationship between physical activity and overweight status. Although diverse classifications of race and ethnicity were available, there was insufficient power to evaluate based on individual ethnic groups, so that only comparison of white and non-white respondents was possible. By combining African Americans with Hispanics, Asians, Native Americans and mixed races, we may miss characterizing important risk differences between ethnic groups. If for example, African Americans were actually less likely to be physically active and more likely to be overweight, race may be acting as a positive confounder, overestimating the protective effect of physical activity on overweight. If African Americans were both more likely to be active and overweight, race would act as a negative confounder in this relationship (Mehio-Sibai, Feinleib, Sibai, & Armenian, 2005). Portland, OR is a predominantly white city, with non-Hispanic whites making up 79% of the county population at the time of the study, which limits the generalizability of the results to more diverse regions.

Additionally, the relatively narrow age range of 10-14 years in the present study may have been too small to detect meaningful differences by age. Unlike the present study, other studies have found that physical activity decreased significantly with increasing age (Nader et al., 2008).

There are major limitations to the diet variables used in the present study. The questionnaire included a dietary recall scale that was not validated in individuals under age 20, and was based on diet recall over the past month (G. Block et al., 2000) which may be difficult to conceptualize for youth. The lack of any association of diet with overweight status in this study could also be explained by underreporting of food intake by overweight and obese individuals, which is a recognized problem with adults (Patrick et al., 2004).

Finally, the measure of neighborhood parks used in this study may not have accurately discriminated between the qualities of physical activity resources available. Portland, OR has a high density of parks, as was reflected in 84.6% of participants responding that they somewhat or strongly agreed with the statement “There are playgrounds, parks, or gyms close to my home, or that my family can get to easily.” Measures assessing neighborhood safety and quality of parks and resources may be more informative, as would more objective measures of neighborhood resources. These potential measurement errors may lead to under or overestimation of the effect of inadequate physical activity on overweight status.

As this study design was cross-sectional, we are unable to determine a cause and effect relationship between physical activity level and overweight status. Low levels of physical activity could be either a cause or a consequence of obesity (Elgar, Roberts, Moore, & Tudor-Smith, 2005). Reverse causation is certainly plausible. Overweight youth may be less likely to participate in organized sports due to fears of being teased, less social support, or lower levels of self-efficacy (Must & Tybor, 2005). Longitudinal cohort studies are needed to better elucidate this relationship. The ADOLPA study provides an opportunity for future research in this area, with 8 years of follow up data available.

Implications

Reducing the prevalence of childhood and adolescent obesity is a national health goal in the US. The US Department of Health and Human Services considers physical activity and overweight and obesity as two of the top ten leading health indicators for the nation (U.S. Department of Health and Human Services, 2000). Despite existing prevention strategies, recent estimates indicate that the prevalence of overweight in adolescents is increasing (Ogden et al., 2006). Our study has identified risk and protective factors for youth overweight and obesity which should help inform prevention strategies that emphasize increasing daily physical activity and decreasing sedentary behavior. In this study, boys and girls attaining more than 60 minutes a day of physical activity, were significantly less likely to be overweight. Although the highest level of activity was associated with the lowest risk of obesity, youth achieving at least 10,000 steps per day also had a decreased risk of overweight. Prevention strategies that emphasize increasing daily activities such as walking and playing outside may be as effective as sports based programs. The American Academy of Pediatrics policy statement on preventing childhood obesity recommends that physical activity be promoted at home, in the community and at school (Council on Sports Medicine and Fitness & Council on School Health, 2006). School based programs provide an opportunity to reach the greatest proportion of youth; however physical education programs have often been unsuccessful in preventing obesity (Council on Sports Medicine and Fitness & Council on School Health, 2006). To improve PE curricula, the AAP recommends emphasizing development of life-long physical activity skills (Council on Sports Medicine and Fitness & Council on School Health, 2006).

The results of this study also suggest that prevention strategies should target limiting television viewing. This is also a goal promoted by the AAP, which recommends that youth watch no more than 2 hours of quality programming per day (Council on Sports Medicine and Fitness & Council on School Health, 2006). Prevention strategies that target lower income youth may also be useful, as the present study shows that youth in households earning less than the median income were more at risk of overweight. More research evaluating modifiable risk factors will be needed to develop effective prevention and intervention strategies to reduce the high rates of adolescent overweight and obesity.

OVERALL SUMMARY AND CONCLUSIONS

Childhood and adolescent obesity is a significant and increasing problem in the United States. Identifying modifiable risk factors will be important for developing strategies to reduce the prevalence of overweight and obesity in our youth. In the present study, we evaluated the association between physical activity and overweight and obesity among 365 participants age 10-14 enrolled in Oregon Research Institute's Social Influences on Adolescent Physical Activity Study (ADOLPA) in 1999-2000. 44.7% of participants were classified as overweight, with BMI for age at or above the 85th percentile, and 23% were classified as obese with BMI at or above the 95th percentile for age. 27% of youth met the highest level of physical activity, corresponding to 60 minutes a day of moderate to vigorous physical activity. Girls were significantly more likely than boys to achieve less activity, with 61% of girls at the lowest level compared to 41% of boys. The risk of being overweight or obese was 53.7% for those adolescents in the lowest physical activity level, compared with 41.8 % for those at the moderate level, and 29.6% for those at the highest level. After adjusting for measured confounding exposures, the overall relative decrease in risk of overweight was 36% lower for those with moderate activity and 62% lower for those with the highest level. Overweight status was also associated with increased television viewing and lower household income. The results of this study add weight to the American Academy of Pediatrics guidelines that recommend all children and adolescents get at least 60 minutes a day of moderate to vigorous physical activity and watch less than 2 hours per day of television.

The present study also found that using pedometers as an objective measure of physical activity is an improvement over prior self report studies. Self report measures of activity in the ADOLPA study were poorly correlated with pedometer recordings over the same time period.

Only the question asking youth to compare their physical activity with that of their peers was associated with overweight status. Youth reporting more or much more activity were 38% less likely to be overweight. Pedometers are affordable, easy to use, and provide a more objective measure of activity than self report data, making these instruments valuable research tools in the study of adolescent physical activity. Pedometers can also be valuable intervention tools to motivate youth and quantify physical activity goals. Based on the results of this study, clinicians should recommend at least 12,000 steps per day for 10-14 year old girls and at least 13,000 steps per day for 10-14 year old boys.

Overweight and obese adolescents are more likely to have significant health problems including diabetes and hypertension, and are likely to remain overweight as adults. Reversing the trend towards increased prevalence of obesity is a National health goal identified in *Healthy People 2010.* This study confirms that to reduce the risk of overweight, teens should be physically active for at least 60 minutes per day and should watch less than 2 hours per day of television as recommended by the American Academy of Pediatrics. Prevention strategies that emphasize increasing physical activity through development of life-long physical activity skills should be a priority of national efforts to reduce adolescent obesity.

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