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Predictive Value of Body Mass Index at Age 18 on Adulthood Obesity: Results of a Prospective Survey of an Urban Population

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Abstract

Background & Aims—Overweight children often become obese adults. Our main purpose was to define the risk of teenage obesity as a predictor of adulthood obesity in a population. A secondary aim was to determine whether gender had an effect on the predictive value of teenage obesity. The final goal was to examine the influence of dietary habits on obesity.

Methods—This cross-sectional survey was conducted using convenience sampling of an urban, primarily African American, community. Demographic questions were supplemented by a dietary history and measurement of body anthropometrics.

Results—503 subjects were interviewed, 86% were African American, and mean age was 43. Body mass index at age 18 was the strongest factor associated with current obesity status in univariate and multivariate analysis. 69 (13.7%) of the subjects were overweight at age 18, and 28 (5.6%) were obese. Of the 28 obese teenagers, 22 (78.6%) went on to become obese as adults. Only 2.1% of non-obese adults were obese as teenagers. For females, BMI at age 18 was more predictive of adult BMI than for males. Gain of ≥ 5 BMI units after age 18 was linked to a higher prevalence of diabetes and hypertension. No dietary differences were found between obese and non-obese adults.

Conclusions—Our results provide evidence that high BMI at age 18 is strongly correlated with adulthood obesity, much more so with females than males. Eating habits did not have an impact, suggesting that obesity may be the result of a combination of factors yet to be clearly defined.

Keywords

obesity; minority; nutrition; body mass index

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Introduction

The obesity epidemic has become the third most preventable cause of disease and death in the United States after hypertension and tobacco use ¹. In the last three decades, the US has witnessed a dramatic rise in the prevalence of adulthood obesity. Between 1980 and 2004, obesity doubled among adults from 15% to 33%, and if the trend continues, 75% of adults will be overweight or obese by 2015 ^{2,3}. To assess obesity, body mass index (BMI) has been used as the benchmark. Nonetheless, BMI is not a perfect measure. It cannot distinguish between fat and lean mass, and thus, cannot provide an accurate indication of body fat in muscular individuals ⁴. Despite this shortcoming, BMI has been shown to be a reliable measure for identifying individuals at an increased risk of weight-related morbidity and mortality ⁴.

Elevated BMI among children and adolescents is another serious public health dilemma. Unlike the classifications for adults, children and adolescents aged 2 to 19 are categorized based on BMI percentile, which accounts for age and gender. According to expert recommendations, CDC growth charts from 2000, and a recent update in terminology, overweight is defined as a BMI in the ≥ 85 th percentile, while obese children are in the ≥ 95 th BMI percentile ^{5,6}. Childhood obesity has been on the rise in the United States, and studies have shown that overweight children and adolescents often become obese adults ⁷. Between 1980 and 2003, the prevalence of overweight children tripled from 6% to 19% in the United States ^{2,7}. The prevalence of overweight adolescents aged 12 to 19 was 10.5% between 1988 and 1994, but has sharply increased to 15.5% between 1999 and 2000 ⁸. Between 1999 and 2006, among non-Hispanic white, non-Hispanic black, and Mexican ethnicities in the US, the prevalence of obese children and adolescents actually showed no significant change ⁹. Despite this plateau, the 2007 to 2008 National Health and Nutrition Examination Survey indicated that 17% of US children and adolescents are obese ⁹.

Obesity is a significant risk factor for the development of a number of co-morbidities ^{10–12}. For example, a twenty kilogram weight gain after age 18 has been shown to increase the risk for diabetes by as much as 15-fold, while a twenty kilogram reduction correlates with nearly zero risk ¹³. Moreover, higher body weight has been associated with increased overall mortality and premature death ^{13–15}. In children, obese non-diabetics were shown to be at the greatest risk for death in early adulthood ¹⁵. In adults, overweight and obese non-smokers were shown to live approximately three and seven years less than their normal-weight counterparts, respectively ¹³.

With the prevalence and health consequences of obesity in mind, the main purpose of this study was to further define the risk of teenage obesity as a predictor of adulthood obesity. To accomplish this, we provide data for an understudied population - urban, impoverished, African Americans. A secondary aim was to determine whether gender had a differential effect on the predictive value of teenage obesity. The final goal was to explore dietary habits and their impact on weight status.

Patients and Methods

Patients

We restricted our cross-sectional survey to adults living in the zip code where Temple University Hospital is centrally located. The 19140 zip code represents a 3.1 mi² region of North Philadelphia, PA. In census data from 2000, there were 57,125 citizens of whom 74.3% were ≥ 18 years old (www.city-data.com/zips/19140). As of 2000, there were 34,703 (60.7%) black and 19,720 (34.5%) Hispanic citizens, primarily from Puerto Rico, living in

this zip code. It is an impoverished region where the median family income is \$20,077 and median home value of \$30,200.

Survey Data

Our survey consisted of demographic questions, anthropometric data (height, weight, waist and hip circumference), alcohol and tobacco use, medical problems, medications, exercise habits, and dietary habits (See Appendix). A standard alcohol drink was described in the survey and examples shown. Examples of standard drinks included a 12-US-fluid-ounce (350 ml) glass of beer, a 5-US-fluid-ounce (150 ml) glass of wine, or a 1.5-US-fluid-ounce (44 ml) glass of a 40% (80 proof) spirit. We asked subjects to recall their weight at age 18 to the best of their ability. In the case of 18 year old subjects, this weight represented their current weight. BMI at age 18 and corresponding percentiles were derived from weight reported for age 18 with assumption of no change from current height. We utilized CDC guidelines to define overweight at age 18 as having a BMI percentile between 85 and 95 and obese as a BMI percentile ≥ 95 ^{5,6}.

Survey Methodology

Our goal was to interview a representative sample of subjects living in the targeted region. Subjects were voluntarily recruited at a retail store located two blocks from our hospital. A booth was placed in the front of the store staffed by a member of the research team. The banner on the booth advertised the survey as a “Health Survey” and did not indicate the nature of the questions. Only individuals ≥ 18 years residing in the zip code for ≥ 3 years were eligible to participate. We used a cutoff of ≥ 3 years to avoid ecological confounding. Subjects were required to produce a picture identification (e.g. driver’s license) confirming they resided in the 19140 zip code and were over 18. Subjects agreeing to participate were directed to a private location within the store where they completed the survey and underwent anthropometric measurements. Administration of the questionnaire was approved by our Institutional Review Board.

Statistical Analysis

The primary outcome variable was the level of obesity in adulthood as measured by the body mass index. According to the World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC), a BMI of ≥ 30 kg/m² has been defined as obese for adults aged 20 and older^{6,9}. For univariate analysis, BMI was dichotomized at a value of 30, categorizing subjects as “non-obese” or “obese”. After confirming distributional assumptions, comparisons of categorical and continuous predictor variables were accomplished using either the χ^2 statistic or two-sample independent t-test. Non-parametric methodology was used as needed for skewed distributions. The Mantel-Haenszel common odds ratio estimate was calculated for univariate categorical comparisons. A multivariable linear regression was performed using explanatory variables of interest primarily including those found to be significant ($P < 0.05$) by unadjusted analysis. Here, adulthood BMI was considered as a continuous variable. Backward elimination of predictor variables was performed in order to simplify the final model without reducing the overall R^2 . All respondent data was recorded using Microsoft Access (Microsoft, Redmond, WA) and downloaded into IBM SPSS Statistics 18 (IBM, Chicago IL) for analysis.

Results

Participants

Overall, 503 subjects were interviewed. Study subjects were dichotomized at the cut point of BMI = 30 (Table 1). Over 80% of subjects were African American, reflective of the

demographics of the surveyed community. The age range of the subjects was 18 to 91, with the mean age of the subjects around 43 years old and a higher prevalence of younger individuals (< 30) in the non-obese group. The majority of participants were females, and most subjects had health insurance and at least a high school education.

Not surprisingly, obese subjects had a significantly greater waist circumference and waist-to-hip ratio than their non-obese counterparts. Subjects with obesity were more likely to be insured (81.0 vs. 72.0%; $P = 0.02$). Coverage was needed by this group as their prevalence of diabetes (16.0 vs. 6.8%; $P = 0.001$) and hypertension (46.5 vs. 29.7%; $P < 0.001$) were significantly higher than those without obesity.

Univariate Factors Associated With Adult Obesity

The subject's report of their BMI at age 18 was the strongest factor associated with current obesity status ($P < 0.001$). According to CDC guidelines, 69 (13.7%) of the subjects were overweight at age 18 ($85^{\text{th}} > \text{BMI} < 95^{\text{th}}$ percentile), and 28 (5.6%) were obese ($\text{BMI} \geq 95^{\text{th}}$ percentile)^{5,6}. Of the 28 obese teenagers, 22 (78.6%) went on to be obese as adults. Only 2.1% of non-obese adults were obese as a teenager ($P < 0.001$). Nearly two out of three (62.3%) overweight teenagers were categorized as obese in adulthood, far more than their normal weight counterparts ($P = 0.001$). Figure 1 demonstrates the relationship between BMI at age 18 and current BMI stratified by gender; the R^2 value (or coefficient of determination) is 0.52 for a woman and 0.25 for a man. On univariate analysis, this means that 52% of the current weight of a female can be explained by their weight at age 18, while this number is roughly 25% for a male.

Alcohol consumption, measured in standard drinks per week, appeared to be inversely associated with obesity status. Likewise, participating in aerobic sporting hobbies at least two days per week was inversely associated with obesity. There was no statistical relationship between levels of daily walking and obesity status, although an inverse trend was present. Surprisingly, dietary habits differed little between the groups, except for the higher mean servings of ice cream per week in obese participants.

Health Consequences of Weight Gain

For the entire group, the mean increase in BMI units (current BMI - BMI at age 18) was 6.63 ± 7.0 with a range of -19.3 to 42.57 . The mean increase in BMI for those currently with diabetes was significantly greater than for those without this condition (9.7 ± 8.8 vs. 6.2 ± 6.6 ; $P = 0.001$). The odds ratio for the presence of diabetes for those who gained ≥ 5 BMI units since 18 was 3.74 (95% CI; 1.83–7.67). The difference was also significant for hypertension (8.7 ± 7.9 vs. 5.4 ± 6.0 ; $P < 0.001$). Those with a ≥ 5 BMI unit gain had an OR = 3.36 (95% CI; 2.23 – 5.06) for the development of hypertension. There were no significant differences between genders on the association of weight gain and the development of these two conditions. There was no association found between weight gain and the risk of asthma and depression.

Multivariable Linear Regression

For regression, current BMI was used as the dependent variable. Explanatory variables of interest entered into the regression included BMI at age 18, current age, participation in regular sporting hobbies, city blocks walked per day, and alcoholic drinks consumed per week. Backward elimination methodology removed all variables except BMI at age 18 and current age, which were highly associated with current BMI, and the model demonstrated significant strength ($r = 0.71$). The final regression equation was:

$$\text{Current BMI} = 1.106 (\text{BMI Age 18}) + 0.108 (\text{current age}) - 0.276$$

The slope values represent point estimates; the 95% confidence intervals were 0.965–1.248 for BMI at Age 18 and 0.050 – 0.166 for current age with P value < 0.001 for both slopes. These results indicate, for the entire study group, that current BMI was associated with an approximate one BMI unit increase per decade of life.

We then evaluated gender as an effect modifier on the relationship between BMI at age 18 and current BMI. In stratified regression analyses, again, only BMI at age 18 and current age were associated with current BMI for both genders. The regression equation for each gender is as follows:

$$\begin{aligned} \text{Women: Current BMI} &= 1.128 (\text{BMI Age 18}) + 0.067 (\text{Current age}) + 1.407 \\ \text{Men: Current BMI} &= 0.649 (\text{BMI Age 18}) + 0.088 (\text{Current age}) + 10.104 \end{aligned}$$

Using these equations it is possible to predict the BMI for each gender over time. For example, one can estimate the BMI at age 50 for a female and male, both with a BMI of 30 at age 18. The female's predicted BMI at age 50 would be 38.60 (95% CI; 32.34–44.83), while the male's would be 33.97 (95% CI; 26.424–41.444), a difference of 13.6% for the point estimates. These results highlight the importance of BMI at age 18 which contributes far more significantly to future-predicted BMI in females. This agrees with results from our univariate analysis (Figure 1). Overall in this example, using the point estimates, 87.7% of the female's current BMI would be determined by her BMI at age 18. For the male, only 57.3% of his current BMI would be attributed to his BMI at age 18. We substituted BMI percentile for the raw score and performed each of the above exercises; no significant differences in the model were identified.

Discussion

From our largely minority study group consisting of urban impoverished African Americans, we determined that BMI at age 18 was strongly predictive of obesity later in adulthood. Overweight and obese teenagers were far more likely to be obese adults compared to their normal weight counterparts ($P < 0.001$). We also found that BMI at age 18 had greater predictive performance for adult BMI in girls compared to boys. Fifty two percent of a woman's adult BMI could be attributed to her weight at age 18. For men, 25% of their adult weight could be predicted from their BMI at age 18. In regression modeling, which included the subject's current age, this same relationship was seen. Weight gain in our study group was not without medical consequences. We found that, for both men and women, the risk for the development of both hypertension and diabetes was increased greater than three-fold in individuals who gained more than 5 BMI units after age 18. Our results highlight the importance of obesity prevention in adolescents in not only the African American community, but in the overall population.

Another finding of our study is the differential predictive value of BMI at age 18 on adulthood obesity in men and women. BMI at age 18 made a more significant contribution to adult BMI value specifically in females, relative to males. This finding is consistent with the results of a previous study that looked at longitudinal obesity trends from adolescence to the third decade of life across sex and various ethnicities. Gordon-Larsen et al demonstrated that adolescent obesity (aged 12 to 21) was highest among non-Hispanic black females, and 95% remained obese into their third decade¹⁶. Other data support that non-Hispanic black adult females have the greatest likelihood of being obese, relative to non-Hispanic whites

and Mexican American adult females; obesity has been reported at an estimated 50% among non-Hispanic black adult females between 1999 and 2008 ¹¹.

Although our results on the relationship between BMI at age 18 and adulthood obesity are specific for a community of minority individuals living in the US, it confirms previous findings not limited to a single population. Similar to prior studies with alternative survey approaches, we came to the same conclusion concerning the fate of obese children across ethnicities ¹⁷. In the early 1990s, based on results from the Muscatine Coronary Risk Factor Project, Clarke et al concluded that obese children had a 2- to 6.5-fold higher risk of becoming obese adults compared to non-obese children ¹⁸. In 2001, using data from the Newcastle Thousand Families prospective cohort study, Wright et al determined that childhood BMI had a moderate and significant association with adult BMI ¹⁹. Their findings revealed that children above the 90th percentile for BMI at ages 9 and 13 were five to nine times more likely to be obese in adulthood compared to children below the 25th percentile ¹⁹. Finally, reflecting on findings from the Child and Adolescent Trial for Cardiovascular Health in 2008, Stovitz et al also demonstrated that being overweight or obese in childhood likely carried over into adulthood. Out of 845 children who had a BMI over the 80th percentile, 40% of children went on to become overweight, and another 35% went on to become obese ²⁰.

African Americans, along with Hispanics, remain particularly impacted by obesity ¹⁶. A number of factors may elucidate why African American females are at the greatest risk. One study suggested that the perception of caregivers during childhood played an important role. Young-Hyman found that despite 70% of 111 African American children being obese or morbidly obese, only 44% of their caregivers actually perceived that their child's weight was a health problem ²¹. In adult African American females, it appears that body image may indirectly correlate with obesity either by promoting it or by influencing their motivation for physical activity. Using data from the Coronary Artery Risk Development In Young Adults (CARDIA) study, Smith et al suggested that African American women were, in fact, more content with a larger body habitus than Caucasian women, after controlling for age and education ²². Therefore, cultural perception and body image may be additional contributors to the high prevalence of obesity among African American females.

A surprising finding of our study was the lack of association between dietary choices and BMI. A priori we anticipated that obese subjects would have a diet that preferentially included high fat content and foods with increased caloric density. We also anticipated they would dine out more frequently, particularly at fast food restaurants. The only difference found was in the frequency of ice cream consumption, probably a small part of overall caloric intake using our questionnaire. We did find an increase in regular sporting activities and a trend toward increased overall walking (although not statistically significant, $P=0.09$) in the leaner group of adults in univariate analysis. Alcohol intake appeared to be protective against obesity but, similar to physical activity parameters, was not associated with adult BMI in regression analysis.

As with any observational study, there are important strengths and weaknesses. A strength is that we interviewed a large number of subjects from a homogeneous urban population. Rather than relying on mailed surveys, we performed convenience sampling of the community to obtain a relatively unbiased study group. We tried to exclude ecological confounding by interviewing permanent residents of the targeted community. One limitation is that our survey methodology did exclude certain participants, such as the homebound, the incarcerated, and the mentally disabled. Furthermore, because individuals had to show proof of residence, which would be verified by examining a valid driver's license, another limitation would be the introduction of selection bias (i.e. study participant would have to be

a driver). Nonetheless, this removes the possibility of confounding if the individual is a transient member of the targeted community.

Another limitation of the study is the potential for recall bias both in the measurement of diet composition and weight at age 18. However, we suspect that recall bias should be non-differential, as there was no motivation for subjects to answer dishonestly. Subjects seemed to know their precise weight in late adolescence / early adulthood, and whether this included the time period when they were 18 years old was not verified. Although no attempt was made to validate patient weight at age 18, this would be extremely difficult to validate in a cross-sectional study, since resources (i.e. school or military records) would be difficult to procure.

For the investigation of eating habits, we preferred our ad hoc questionnaire over the Food Frequency Questionnaire (FFQ), a dietary assessment tool widely utilized in epidemiological studies. The FFQ could be used to estimate total calories and distribution of protein, carbohydrate, and fat in the diet, but these estimates would lack considerably in precision. Moreover, the length of the survey would be disadvantageous, and questionnaire responses would also be susceptible to recall bias. In summary, the FFQ would provide little additional information over the questionnaire we developed for the study.

In conclusion, in an urban, primarily African American, study group, we found that individuals who are currently obese were far more likely to be overweight or obese at age 18. For females, BMI at age 18 was more predictive of adult BMI than for males. Gaining weight after age 18 has important consequences, as we were able to link this occurrence with prevalent diabetes and hypertension. Reversing the trend of childhood obesity has been the focus of the Task Force on Community Preventive Services. The results from recent recommendations, such as interventions aimed at promoting physical activity within the community and reducing television screen time, will hopefully be successful^{9,23}.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

BMI as a teenager and final adult BMI stratified by gender.

Graph shows least-squares fit line and 95% confidence intervals.

BMI – body mass index

Table 1

Predictors of obesity status in interviewed subjects.

VARIABLE*	BMI < 30 NON-OBESE N = 293	BMI ≥ 30 OBESE N = 200	P VALUE
Age **			<0.001
18–30	104 (35.5)	43 (21.5)	
31–50	88 (30.0)	90 (45.0)	
>50	99 (33.8)	65 (32.5)	
Male	124 (42.3)	69 (34.8)	0.10
Race			0.09
African American	255 (87.6)	171 (85.9)	
Hispanic	12 (4.1)	17 (8.5)	
Caucasian	8 (2.7)	6 (3.0)	
Asian	16 (5.5)	5 (2.5)	
High School Graduate	229 (78.4)	165 (82.5)	0.27
Health Insured	211 (72.0)	162 (81.0)	0.02
Waist Circumference †	34.5 (4.4)	42.4 (6.2)	< 0.001
Waist: Hip Ratio			
Male	0.93 (0.12)	1.00 (0.13)	0.001
Female	0.88 (0.13)	0.92 (0.14)	0.02
Body Mass Index Age 18			
Calculated	21.3 (4.5)	25.5 (7.9)	
Percentile	41.2 (32.4)	64.8 (29.6)	< 0.001
Smoking Status			0.29
Never	111 (37.9)	88 (44.7)	
Former	60 (20.5)	33 (16.8)	
Current	122 (41.6)	76 (38.6)	
Alcoholic Drinks/wk	5.9 (10.8)	3.4 (4.6)	0.01
Health Disorders			
Depression	9 (3.1)	10 (5.0)	0.28
Hypertension	87 (29.7)	93 (46.5)	<0.001
Asthma/COPD	27 (9.2)	24 (12.0)	0.32
Diabetes	20 (6.8)	32 (16.0)	0.001
Sporting Hobby (yes/no)	96 (32.8)	42 (21.0)	0.004
Median city blocks walk/d	12.0	10.0	0.09

VARIABLE*	BMI < 30 NON-OBESE N = 293	BMI ≥ 30 OBESE N = 200	P VALUE
Diet			
Slices Bread/d	2.2 (1.3)	2.1 (1.3)	0.16
Servings Cereal/wk	2.3 (1.6)	2.2 (1.5)	0.52
Strict Vegetarian	14 (4.8)	6 (3.0)	0.33
Pork Servings/wk	1.4 (1.3)	1.5 (1.3)	0.32
Beef Servings/wk	2.2 (1.3)	2.2 (1.2)	0.95
Chicken Servings/wk	3.3 (1.3)	3.3 (1.3)	0.70
Fish Servings/wk	2.0 (1.3)	2.1 (1.4)	0.47
Fruit Servings/d	2.3 (1.6)	2.3 (1.5)	0.73
Cooked Vegetable Servings/d	2.4 (1.4)	2.4 (1.4)	0.93
Uncooked Vegetable Servings/d	3.3 (1.5)	3.2 (1.5)	0.54
Coffee Drinks/d	0.8 (1.1)	0.8 (1.1)	0.87
Soda Drinks/d	1.7 (1.5)	1.8 (1.6)	0.29
Cake/Pie Servings/wk	2.7 (1.7)	2.9 (1.5)	0.14
Ice Cream Servings/wk	1.9 (1.4)	2.2 (1.5)	0.03
Candy Servings/wk	2.7 (1.8)	2.9 (1.7)	0.12
Dine Out of home/wk	1.6 (1.4)	1.8 (1.4)	0.16

* There were a total of 503 subjects interviewed. BMI only available for 493.

** For categorical variables numbers in parenthesis are percent of column total. There existed some missing data points for categorical variables so that sums do not equal column totals.

† For continuous variables numbers in parenthesis are $\pm$ standard deviation