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DIFFERENCES IN THE U.S. TRENDS IN THE PREVALENCE OF OBESITY BASED ON BODY MASS INDEX AND SKINFOLD THICKNESS

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ABSTRACT

There are several ways to measure fatness and obesity, each with its own strengths and weaknesses. The primary measure for tracking the prevalence of obesity has historically been body mass index (BMI). This paper compares long-run trends in the prevalence of obesity when obesity is defined using skinfold thickness instead of body mass index (BMI), using data from the full series of U.S. National Health Examination Surveys. The results indicate that when one uses skinfold thicknesses rather than BMI to define obesity, the rise in the prevalence of obesity is detectable ten to twenty years earlier. This underscores the importance of examining multiple measures of fatness when monitoring or otherwise studying obesity.

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BACKGROUND

According to the U.S. Surgeon General, obesity has reached "nationwide epidemic proportions" in the United States (U.S. Department of Health and Human Services 2001). The rise in obesity is troubling because it is associated with elevated risks of morbidity (Reither et al. 2009; U.S. Department of Health and Human Services 2001), functional limitations (Himes 2000) and mortality (Flegal et al. 2007; U.S. Department of Health and Human Services 2001). In addition, the obese tend to suffer social stigma (Puhl and Heuer 2009) and have a lower probability of marriage (Averett and Korenman 1999).

There is considerable interest in better understanding the reasons that obesity began to rise (Lakdawalla and Philipson 2002; Anderson et al. 2003; Lakdawalla et al. 2005; Cutler et al. 2003; Lakdawalla and Philipson 2002; Philipson and Posner 1999; Gruber and Frakes 2006; Chou et al. 2004), which requires accurately dating the beginning of its increase.

There are many ways to measure fatness and therefore obesity, each with its own strengths and weaknesses (Burkhauser and Cawley 2008). A practical consideration is that few measures of fatness have been consistently collected over time. One measure of fatness that has been consistently collected in nationally representative health surveys is body mass index (BMI), which is calculated as weight in kilograms divided by height in meters squared. The vast majority of previous studies that have dated the beginning of the rise in obesity have defined obesity using BMI and concluded that obesity was relatively constant from roughly 1960 to roughly 1980, after which obesity rose considerably (Flegal et al. 1998, 2002).

However, there is one additional measure of fatness that has been consistently collected in nationally representative health surveys: skinfold thickness. The purpose of this paper is to date the beginning of the rise in obesity when obesity is defined using skinfold thickness, and to determine whether it differs when one uses skinfold thickness rather than BMI to define obesity. In its interest in thinking broadly in order to enrich understanding of the rise in obesity, this paper complements a previous study that considered alternate measures of overweight and obesity using BMI (Joliffe 2004).

The findings of this paper result in new and different interpretations of the rise on obesity over the last 50 years in the U.S. Specifically, the rise in obesity defined using skinfolds is apparent ten to twenty years earlier than the rise in obesity defined using BMI. This implies that the rise in obesity may be due to more gradual and longer running influences than was previously appreciated. It also indicates that if obesity surveillance had monitored multiple measures of fatness, the rise in obesity might have been detected, and public health campaigns could have begun, two decades earlier. In general, because each measure of fatness has its own strengths and weaknesses, research on obesity is enriched by greater consideration of multiple such measures.

DATA AND METHODS

Surveys

This study utilizes the series of nationally representative, cross-sectional health surveys sponsored by the National Center for Health Statistics, Centers for Disease Control and Prevention. The National Health Examination Survey, Cycle I (NHES I) was conducted on a sample of persons aged 18-79 years during 1959-1962. The NHES Cycle 3 (NHES III) was conducted on a sample of youths aged 12-17 years during 1966-1970. The National Health and Nutrition Examination Surveys (NHANES) program began with NHANES I, which was conducted 1971-1975, and was followed by NHANES II (1976-1980), NHANES III (1988-

1994), and NHANES Continuous (1999-2000, 2001-2002, 2003-2004, and 2005-2006) (5-9). In each of these surveys, a nationally representative sample of the US civilian non-institutionalized population was selected using a complex, stratified, multistage probability cluster sampling design.

For adults, there is variation in the upper end of the age range sampled in the various NHES and NHANES surveys. Excluding NHES III, which was devoted solely to youths, data are always collected for those up to age 74, so for the sake of consistency we limit each adult sample to those aged 20-74 years. Categories of race and ethnicity were not consistent across the surveys so all races and ethnicities were pooled. Final sample sizes for youths aged 12-17 are listed in Table 1 and those for adults are listed in Table 3.

BMI, Skinfolds, and Obesity

Each NHES and NHANES survey included physical examinations conducted in a specially-designed and equipped mobile examination center. A survey team including a physician and medical and health technicians measured tricep and subscapular skinfold thicknesses, weight, and height in every survey. Other measures of fatness were also recorded in certain surveys, but the only fatness measures consistently collected from NHES until NHANES 2005-2006 are the two skinfold measures and weight and height. The maximum weight that could be measured was not binding in NHES, and was 400 pounds (182 kg) in NHANES I and II. In NHANES III it was again not binding and in NHANES Continuous it was 440 kg (968 pounds). The top-coding of weight does not affect our classification of individuals, as everyone with the maximum weight is clinically obese.

Body Mass Index (BMI) was calculated as weight in kilograms divided by height in meters squared. Adult obesity was defined in accordance with the National Institutes of Health and the World Health Organization as a BMI of 30 or higher (NHLBI Expert Panel 1998; World Health Organization Consultation on Obesity 2000). Youth obesity was defined using smoothed age-and-gender-specific 85^{th} percentile thresholds for BMI from the NHANES I distribution (Must et al. 1991).

Skinfolds were assessed using calipers at the tricep and subscapular region (below the shoulder blade). In NHES and NHANES I and II, skinfold thicknesses were measured by Lange calipers manufactured by Cambridge Scientific Instruments that have a maximum value of 65 mm. For the examinations associated with NHANES III, a Holtain T/W caliper with a 50 mm maximum was used. For NHANES Continuous, the medical examinations used a Holtain-brand caliper with a 45 mm maximum. In general variability in compression can affect the reliability of skinfold measurements, but the Lange and Holtain calipers used in NHES and NHANES exert a constant pressure (Heymsfield et al. 2004). The NHES and NHANES medical technicians were trained in taking skinfold thicknesses to ensure accuracy and reliability (National Center for Health Statistics 2000).

The NHANES III and NHANES Continuous noted when a skinfold exceeded the capacity of the calipers. The percentage of the examined adult sample with tricep skinfolds larger than the maximum caliper size was as follows: 1.9% in NHANES III and from 3.6% to 5.8% in each of the three surveys in NHANES Continuous. The percentage of the examined adult sample with subscapular skinfolds larger than the maximum caliper size was as follows: 2.4% in NHANES III, 4.5% in NHANES 1999-2000, 1.9% in NHANES 2001-2002, 1.6% in NHANES 2003-2004, and 2.1% in NHANES 2005-06. We do not make use of the subscapular skinfolds for our analysis of youth obesity. For youths, the percentage of the examined sample with tricep skinfolds larger than the maximum caliper size was as follows: 1.4% in NHANES III, 1.5% in NHANES 1999-2000, 1.2% in NHANES 2001-2002, 1.4% in NHANES 2003-2004, and 0.9% in NHANES 2005-06. For all respondents whose skinfold exceeds the maximum caliper size we recode their skinfold thickness to be equal to the maximum caliper size. This top-coding of skinfold thickness does not affect our estimates of the prevalence of obesity because such individuals are obese whether their skinfold is set equal to the maximum caliper size or an even larger number.

In addition to recording whether the skinfold exceeded the maximum caliper size, the NHANES Continuous indicated if the examiner could not obtain a measurement (presumably for reasons other than the skinfold exceeding the maximum caliper size). For adults, the percentage of the examined sample for whom tricep skinfold thickness could not be obtained was 2.8% in NHANES 1999-2000, 5.6% in NHANES 2001-2002, 7.1% in NHANES 2003-2004, and 10.2% in NHANES 2005-06. The percentage of the examined adult sample for which subscapular skinfold thickness could not be obtained was 15.3% in NHANES 1999-2000, 21.4% in NHANES 2001-2002, 20.8% in NHANES 2003-2004, and 27.0% in NHANES 2005-06. For youths, the percentage of the examined sample for whom tricep skinfold thickness could not be obtained was 3.2% in NHANES III, 1.2% in NHANES 1999-2000, 1.9% in NHANES 2001-2002, 3.2% in NHANES 2003-2004, and 3.9% in NHANES 2005-06. When the skinfold could not be obtained, we impute it using the other skinfold thickness, measured BMI, age, age squared, and race and ethnicity; this prediction equation is based on respondents with complete information. These regression models explain 91.2% to 96.4% of the variance in skinfolds, implying that the imputation procedure accurately predicts the missing skinfolds.

The definition of obesity based on skinfold thicknesses differs for youth and adults. Following the literature, we define youth obesity using tricep (but not subscapular) skinfold thickness; specifically, a youth is classified as obese if the tricep skinfold thickness exceeds the smoothed age-and-gender-specific 85^{th} percentile thresholds from the NHANES I distribution (Gortmaker and Dietz 1990; Must et al. 1991).

Adults were classified as obese or non-obese using the following steps. First, body density was predicted using tricep and subscapular skinfold thicknesses (Durnin and Womersley 1974). Second, percent body fat was computed using body density (Durnin and Womersley 1974; Siri 1956). (Use of an alternate equation for converting body density to percent body fat (Brozek et al. 1963) yielded similar trends.) Finally, men were classified as obese if their percent body fat exceeded 25%, and women were classified as obese if their percent body fat exceeded 30% (National Institute of Diabetes and Digestive and Kidney Diseases, Accessed 2007).

Methods

Statistical analyses were carried out using SAS for Windows software (SAS for Windows, Version 9.1.3 Service Pack 3). All analyses excluded pregnant females. The prevalence of obesity was calculated for each age group and in each survey. To avoid having changes in the age distribution of the population affect trends in obesity, the obesity rates in each survey are age- and sex-adjusted based on population counts in the 2000 Census. Specifically, estimates were age-standardized to Census 2000 counts of age groups 12-17 years, 20 to 39 years, 40 to 59 years, and 60-74 years. (We use the age group 12-17 years because that was the age range of NHES III, and we use the adult age groups that are the convention in recent studies of the prevalence of obesity (e.g. Flegal et al. 2002). Adhering to previously-used age ranges facilitates comparisons with the previous literature but has the unfortunate consequence of omitting youths aged 18-19.) For all surveys, estimates are based on the sampling weights associated with the sample that underwent medical examinations. Estimates also take into account the complex survey design, including unequal probabilities of selection, non-response, and deliberate over-sampling of certain groups. Tests of the hypothesis of equality of obesity prevalence over time were conducted, using a significance level of .05.

RESULTS

Youths Aged 12-17 Years

Figure 1 presents the trend between NHES III (1966-70) and NHANES 2005-06 in obesity defined using BMI (denoted with diamond symbols) and obesity defined using skinfold thickness (denoted with square symbols) for youths aged 12-17. The specific estimates by survey, sex, and definition of obesity are provided in Table 1. Table 2 documents the percentage-point changes in obesity between NHES III (1966-70) and NHANES II (1976-80), NHANES II (1976-80) and NHANES Continuous (1999-2005), and the overall change between NHES I (1966-70) and NHANES Continuous (1999-2005); it also lists p values associated with a test of the hypothesis that each trend is equal to zero.

Earlier studies that examined changes in the prevalence of youth obesity defined using BMI concluded that obesity was relatively constant from NHES III to NHANES II (Flegal et al. 1990). Limiting our attention to this range, Figure 1 confirms that obesity defined using BMI experienced little net increase between NHES III and NHANES II because it first rose between NHES III and NHANES I and then fell between NHANES I and NHANES II. In contrast, obesity defined using skinfolds rose monotonically from the first to the second to the third survey. Table 1 provides the exact statistics; for both genders pooled BMI-defined obesity first rose from 14.6 to 18.4 percent, then fell to 16.6 percent, while skinfold-defined obesity rose from 10.1 to 14.5 to 15.2 percent.

Table 2 reports the changes in prevalence from survey to survey in percentage points and also indicates whether the change was statistically significant. Table 2 confirms that the 5.1 percentage point change between NHES III and NHANES II in skinfold-defined obesity was statistically significant (P<.001), and that the overall change of 2.1 percentage points over the same period in BMI-defined obesity was also statistically significant at the 1 percent level (P=0.01). When the changes are examined separately by sex, the point estimates of the change from NHES III to NHANES II remain positive for both measures of obesity, but they are only statistically significant for obesity defined using skinfolds.

Next turning to the latest five surveys, Figure 1 confirms that the trend in both measures of obesity is generally (though not monotonically) upward. Table 2 reports the change from NHANES II to NHANES 2005-06. An 11 percentage point rise in skinfold-defined obesity and a 15.6 percentage point rise in BMI-defined obesity are both statistically significant at the 1 percent level.

Looking over the entire range of data, the long-term trend from NHES III to NHANES 2005-06 is a rise of 16.1 percentage points in skinfold-defined obesity and a rise of 17.7 percentage points in BMI-defined obesity. Both values are statistically significant (P<.001).

Adults Aged 20-74 Years

The prevalence of adult obesity defined using BMI and skinfold thicknesses are presented in Table 3. Table 4 documents the percentage-point changes in obesity between NHES I and

NHANES II, NHANES II and NHANES Continuous, and the overall change between NHES I and NHANES Continuous; it also lists p values associated with a test of the hypothesis that each trend is equal to zero. Earlier studies that examined changes in the prevalence of adult obesity defined using BMI have concluded that obesity was relatively constant from NHES I to NHANES II (Flegal et al. 1998, 2002). Tables 3 and 4 confirm that finding; obesity defined using BMI rose from 14.4% to 14.7% between NHES I and NHANES II (P=.34) before rising to 31.8% in NHANES 2005-2006 (P<.001). However, when skinfold thicknesses are used to define obesity, the rise in obesity is apparent beginning with the earliest data; it rises from 26.5% to 34.7% between NHES I and NHANES II (P<.001) and continues to 43.4% in NHANES 2005-2006 (P<.001). Figure 2 illustrates that the rise in obesity defined using skinfold thickness (denoted with square symbols) began before the rise in obesity defined using BMI (denoted with diamond symbols).

Table 3 also shows the prevalence of obesity by gender and age group in each survey. For each gender, with all ages 20-74 pooled, the rise in skinfold-defined obesity is apparent between NHES I and NHANES II, while the rise in BMI-defined obesity is only apparent between NHANES II and NHANES III. For men aged 20-74, the prevalence of skinfold-defined obesity rises from 13.5% to 18.5% between NHES I and NHANES II (P<.001), whereas the prevalence of BMI-defined obesity only rises from 11.7% to 12.4% over the same period (P=.24). For women aged 20-74, the prevalence of skinfold-defined obesity increases from 39.1% to 50.4% between NHES I and NHANES II (P<.001), whereas BMI-defined obesity dips slightly from 17.0% to 16.9% over the same period (P=.45).

Looking within age groups by gender, the same pattern is present for men 40-59 and 60-74 and women 20-39 and 40-59. Among men 20-39 and women 60-74 there is little increase in skinfold-defined obesity and a decline in BMI-defined obesity.

DISCUSSION

Previous research that used BMI to define obesity dated the beginning of the rise in U.S. obesity, among both youths and adults, from NHANES II (1976-80) to NHANES III (1988-94). This article finds that when skinfold thickness is used to define obesity, the rise in obesity is apparent starting from the earliest surveys, which for adults is NHES I (1959-62), and which for youths is NHES III (1966-70).

This implies that the rise in obesity may be due to more gradual and longer running influences than was previously appreciated. Previous research has investigated the extent to which the rise in BMI-defined obesity was due to specific causes, such as falling food prices (Lakdawalla and Philipson 2002), increasing maternal employment (Anderson et al. 2003), technological innovation in food preparation and preservation (Cutler et al. 2003), school finances (Anderson and Butcher 2006), and reduced smoking (Chou et al. 2004; Gruber and Frakes 2006), but this literature, guided by the findings based on BMI, may be focusing too narrowly on recent events and missing the earlier influences that contributed to the rise in skinfold-defined obesity ten to twenty years earlier.

These findings relate to a twenty-year-old controversy over the use of skinfold thicknesses and BMI to define adolescent obesity. A study published in 1987 (Gortmaker et al. 1987) found a rise between NHES III and NHANES II (i.e. from 1966-1980) in the prevalence of adolescent obesity defined using skinfold thickness. A study published the next year (Harlan et al. 1988) opposed the use of skinfolds to measure trends between NHES and NHANES, arguing: "The main point at issue is how to interpret the observation that, for adolescents, body mass index does not show a trend across surveys but skinfold measurements do show a trend. One possibility is that from 1967 to 1980 the adolescent population got fatter at a constant body mass index…Another possibility is that the small differences in skinfold measurements across surveys are an artifact of measurement error. Neither of these possibilities can be ruled out with the available data." (Flegal et al. 1990).

This paper sheds light on that debate. Figures 1 and 2 include twenty-five years of data from five surveys that were not available during the original exchange. With the benefit of hindsight, one can see from Figures 1 and 2 and Tables 1 and 2 that, among both youths and adults, skinfold-defined obesity began rising one to two surveys earlier than BMI-defined obesity, and that this was a long-term trend. Relative to the limited information available at the time of the original exchange, the 25 years of additional data lend credibility to the claim that skinfold-defined obesity was rising at a time that BMI-defined obesity was not. In other words, the rise in skinfold-defined obesity did not occur in the complete absence of a rise in BMI-defined obesity; it simply preceded it. A rise in obesity defined using skinfolds may be what forecasters call a "leading indicator" of a rise in obesity defined using BMI.

It is possible for obesity to be rising by one measure but not by another because various indices of fatness measure different things and the threshold for obesity is drawn at different points in their distributions (NHLBI Expert Panel 1998; World Health Organization 2000; National Institute of Diabetes and Digestive and Kidney Diseases, Accessed 2007). For example, obesity defined using skinfolds classifies more people as obese (i.e. it is a lower threshold) than obesity defined using BMI, so it is possible that people in the healthy weight and overweight categories of BMI gained enough fat to make them obese by skinfold thickness but not enough fat to make them obese by BMI. In other words, the rise in obesity defined using skinfolds reflected increases in fatness among people who remained pre-obese according to BMI. Consistent with this hypothesis, we calculate that the prevalence of skinfold-defined obesity among adults rose 20.6% among those with BMI less than 30 and rose only 9.7% among those with BMI greater than or equal to 30, between NHES and NHANES I. Further evidence that fatness measures can move independently of each other appears in a recent study (Elobeid et al. 2007) that finds that waist circumference rose faster between 1959 and 2004 than one would expect given changes in BMI over the same period.

In 2001, the U.S. Surgeon General issued a “call to action” on obesity (U.S. Department of Health and Human Services 2001) and the World Health Organization has stated that the need for public health action is “urgent” (World Health Organization 2004). In recent years, states have increasingly taken legislative action to prevent or reduce obesity (Cawley and Liu 2008). If more previous research had used skinfolds to monitor obesity, the rise in obesity might have been detected a decade or two sooner. If that had happened, public health and public policy responses might have been implemented, and progress in preventing obesity could have begun, earlier.

BMI and skinfold thickness are both widely accepted indices for measuring fatness and defining obesity (World Health Organization 1995; Mei et al. 2002). For example, both are frequently-used endpoints to evaluate anti-obesity interventions (Flodmark et al. 2006; Doak et al. 2006). A comparison of the two measures using NHANES I data concluded that BMI and skinfold thickness are “interchangeable for many epidemiologic research applications” (Must et al. 1991). Studies of NHANES III data to validate BMI as a predictor of body fat have used skinfold thickness as the gold standard for subcutaneous fat (Mei et al. 2002). Studies have used both BMI and skinfold thickness to track short-term trends in obesity, although studies using skinfold thickness are far less common (Freedman et al. 1997; Kromeyer-Hauschild and Jaeger 1998; Moreno et al. 2001; Dollman and Pilgrim 2005), and the series of NHES and NHANES surveys remained unexploited for the present purpose.

BMI and skinfold thickness each have their strengths and weaknesses as measures of fatness and obesity. BMI is widely used because it is easy to calculate, but it is a noisy measure of fatness because it does not distinguish fat from muscle, bone, and other lean body mass (Yusuf et al. 2005; Kragelund and Omland 2005; Gallagher et al. 1996; Smalley et al. 1990; Garn et al. 1986). As a result, BMI overestimates fatness among those who are muscular (U.S. Department of Health and Human Services 2001; Prentice and Jebb 2001).

A strength of skinfold thickness is that it distinguishes fat from muscle. Because between 70-90% of all adipose tissue is subcutaneous, skinfold thicknesses accurately measure total body fat (Heymsfield et al. 2004). In addition, the tricep and subscapular sites are preferred because of accessibility, ease of measurement, and high correlation with total body fat (Heymsfield et al. 2004). However, a limitation of skinfold thickness is that tricep and subscapular skinfolds do not measure central adiposity, which has been shown to be associated with a greater risk of morbidity and mortality (National Institutes of Health 1998). Skinfolds are less accurate in the very lean and very obese (Deurenburg and Deurenburg-Yap 2004), but that is less of a problem for this analysis, which focuses on obesity status rather than variation in fatness within clinical weight classifications. Another limitation is that interviewers were more likely to be unable to obtain skinfold measurements than weight in pounds or kilograms. Also, using skinfolds to define obesity for adults involves the use of two conversion equations (from skinfold thickness to body density, and body density to percent body fat). Consequently, the body fat percentage calculated from skinfolds reflects the cumulative error from the application of two models. A limitation of both BMI and skinfolds is that they may ignore differences across ethnic groups in body fat or its distribution (Burkhauser and Cawley 2008; Deurenburg and Deurenburg-Yap 2004).

This paper emphatically does not take the position that skinfold thickness is superior to BMI as a measure of fatness. This paper's position is: given the enormous attention devoted to trends in obesity based on BMI, an examination of trends in obesity based on the only alternative measure of fatness that is consistently available -- skinfold thickness -- is worthwhile.

There are multiple valid measures of fatness and yet they yield different trends in obesity. This suggests that one should monitor multiple measures of fatness to increase the probability of detecting trends early. Even more generally, research on obesity can be enriched by greater consideration of alternative measures of fatness and body composition.

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Table 1. Trends in the Prevalence of Obesity Defined Using Skinfolds or BMI for Youths Aged 12-17 by Sex, 1966-2006*

Sex	Age, y†	Measure of Obesity	NHES III, 1966-1970 (n = 6,710)	NHANES I, 1971-1975 (n = 4,699)	NHANES II, 1976-1980 (n = 4,344)	NHANES III, 1988-1994 (n = 6,264)	NHANES Continuous, 1999-2000 (n = 3.266)	NHANES Continuous, 2001-2002 (n = 3,438)	NHANES Continuous, 2003-2004 (n = 3,030)	NHANES Continuous, 2005-2006 (n = 3,114)
Both Sexes	12-17	Skinfold	10.1	14.5	15.2	20.8	27.7	26.3	29.4	26.2
		BMI	14.6	18.4	16.6	26.9	30.0	31.1	34.2	32.3
Males	12-17	Skinfold	10.5	13.5	13.8	20.8	28.9	28.9	31.0	29.6
		BMI	14.1	15.8	16.7	26.9	29.7	32.7	36.9	31.7
Females	12-17	Skinfold	9.7	15.5	16.7	20.7	26.4	23.6	27.7	22.6
		BMI	15.1	21.1	16.6	26.9	30.3	29.5	31.3	32.8

*NHES indicates National Health Examination Survey; and NHANES, National Health and Nutrition Examination Survey.
†Estimated prevalences for ages 12-17 years were age-standardized by the direct method to the 2000 Census population using each individual age from 12 to 17 years.

Table 2. Changes in the Prevalence of Obesity Defined Using Skinfolds or BMI Between the NHES III, NHANES II, and NHANES 2005-2006 for Youths Aged 12-17 by Sex*

			Change NHES III (1966-1970) to NHANES II (1976-1980)		Change NHANES II (1976-1980) to NHANES 2005-2006		Change NHES III (1966-1970) to NHANES 2005-2006	
Sex	**Age, y†**	**Measure of Obesity**	**Percentage Points, (95% CI)**	***P* Value**	**Percentage Points, (95% CI)**	***P* Value**	**Percentage Points, (95% CI)**	***P* Value**
Both Sexes	12-17	Skinfold	5.1 (3.3 to 6.8)	*P<.001*	11.0 (8.3 to 13.7)	*P<.001*	16.1 (13.8 to 18.4)	*P<.001*
		BMI	2.1 (0.2 to 3.9)	0.01	15.6 (12.8 to 18.5)	*P<.001*	17.7 (15.2 to 20.2)	*P<.001*
Males	12-17	Skinfold	3.3 (1.0 to 5.6)	*P<.001*	15.8 (12.0 to 19.6)	*P<.001*	19.1 (15.8 to 22.5)	*P<.001*
		BMI	2.6 (0.1 to 5.1)	0.02	15.1 (11.1 to 19.0)	*P<.001*	17.7 (14.2 to 21.1)	*P<.001*
Females	12-17	Skinfold	7.0 (4.4 to 9.6)	*P<.001*	5.9 (2.1 to 9.8)	*P<.001*	12.9 (9.7 to 16.1)	*P<.001*
		BMI	1.5 (-1.2 to 4.2)	0.14	16.2 (12.1 to 20.4)	*P<.001*	17.7 (14.2 to 21.3)	*P<.001*

*NHES indicates National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey; and CI, confidence interval.
†Estimated prevalences for ages 12-17 years were age-standardized by the direct method to the 2000 Census population using each individual age from 12 to 17 years.

Table 3. Trends in the Age-Adjusted and Age-Specific Prevalence of Skinfold Based Obesity and BMI Based Obesity for Adults Aged 20-74 Years, 1959-2006*

Sex	Age, y†	Measure of Obesity	Prevalence, %							
			NHES I, 1959-1962 (n = 6,126)	NHANES I, 1971-1975 (n = 15,904)	NHANES II, 1976-1980 (n = 11,777)	NHANES III, 1988-1994 (n = 14,041)	NHANES Continuous, 1999-2000 (n = 3.528)	2001-2002 (n = 3,823)	2003-2004 (n = 3,557)	2005-2006 (n = 3,557)
Both Sexes	20-74	Skinfold	26.5	29.3	34.7	37.6	42.4	41.9	45.0	43.4
		BMI	14.4	14.4	14.7	22.7	29.8	29.6	31.0	31.8
Men	20-74	Skinfold	13.5	12.9	18.5	19.9	25.0	25.1	27.8	27.8
		BMI	11.7	12.5	12.4	19.9	26.4	26.6	29.3	31.3
	20-39	Skinfold	10.3	7.5	11.2	10.3	17.0	16.2	16.3	16.7
		BMI	10.5	10.4	9.7	14.1	22.1	20.9	26.2	26.1
	40-59	Skinfold	17.1	18.8	24.4	26.2	29.6	30.5	36.9	36.3
		BMI	13.8	15.8	14.8	25.0	27.9	30.3	31.6	35.4
	60-74	Skinfold	13.2	12.5	23.1	29.5	35.3	35.2	35.8	36.4
		BMI	9.6	9.7	13.4	22.8	34.0	32.9	32.0	34.7
Women	20-74	Skinfold	39.1	45.2	50.4	54.8	59.2	58.1	61.7	58.6
		BMI	17.0	16.2	16.9	25.4	33.0	32.4	32.6	32.4
	20-39	Skinfold	20.9	29.0	33.0	37.7	47.7	43.0	47.5	42.4
		BMI	10.2	11.3	12.3	20.3	27.6	28.1	27.6	25.8
	40-59	Skinfold	50.1	55.9	63.7	70.0	67.3	68.7	73.1	71.0
		BMI	19.8	18.0	20.2	29.9	36.3	34.2	37.5	37.1
	60-74	Skinfold	60.6	61.8	64.0	62.2	69.7	72.2	71.3	70.8
		BMI	28.3	24.9	21.1	27.6	39.4	39.4	33.9	38.1

*NHES indicates National Health Examination Survey; and NHANES, National Health and Nutrition Examination Survey.

†Estimated prevalences for ages 20-74 years were age-standardized by the direct method to the 2000 Census population using age groups 20-39, 40-59, and 60-74 years.

Table 4. Changes in the Prevalence of Skinfold Based Obesity and BMI Based Obesity Between the NHES, NHANES II, and NHANES 2005-2006 by Sex and Age*

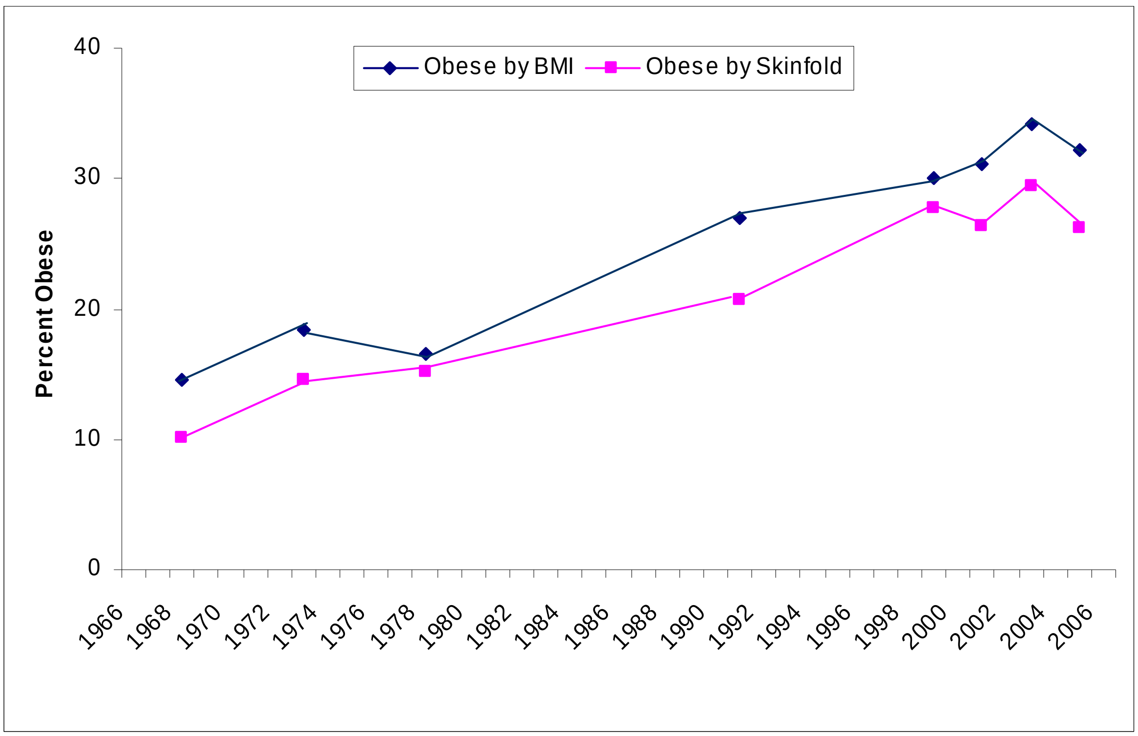
			Change NHES I (1959-1962) to NHANES II (1976-1980)		Change NHANES II (1976-1980) to NHANES 2005-2006		Change NHES I (1959-1962) to NHANES 2005-2006	
Sex	**Age, y†**	**Measure of Obesity**	**Percentage Points, (95% CI)**	***P* Value**	**Percentage Points, (95% CI)**	***P* Value**	**Percentage Points, (95% CI)**	***P* Value**
Both Sexes	20-74	Skinfold	8.2 (6.3 to 10.1)	*P* <.001	8.7 (6.5 to 10.9)	*P* <.001	16.9 (14.9 to 19.0)	*P* <.001
		BMI	0.3 (-1.0 to 1.5)	0.34	17.2 (15.4 to 18.9)	*P* <.001	17.4 (15.6 to 19.2)	*P* <.001
Men	20-74	Skinfold	4.9 (3.0 to 6.9)	*P* <.001	9.4 (6.9 to 11.8)	*P* <.001	14.3 (11.8 to 16.8)	*P* <.001
		BMI	0.6 (-1.1 to 2.3)	0.24	18.9 (16.5 to 21.3)	*P* <.001	19.5 (17.0 to 22.0)	*P* <.001
	20-39	Skinfold	0.9 (-1.5 to 3.2)	0.24	5.5 (2.6 to 8.4)	*P* <.001	6.4 (2.9 to 9.8)	*P* <.001
		BMI	-0.9 (-3.3 to 1.6)	0.24	16.5 (13.1 to 19.9)	*P* <.001	15.6 (11.8 to 19.4)	*P* <.001
	40-59	Skinfold	7.3 (3.7 to 11.0)	*P* <.001	11.9 (7.3 to 16.5)	*P* <.001	19.3 (14.9 to 23.6)	*P* <.001
		BMI	1.0 (-1.9 to 3.9)	0.25	20.6 (16.5 to 24.7)	*P* <.001	21.6 (17.3 to 25.8)	*P* <.001
	60-74	Skinfold	9.8 (5.4 to 14.3)	*P* <.001	13.3 (8.0 to 18.6)	*P* <.001	23.1 (17.5 to 28.8)	*P* <.001
		BMI	3.8 (0.3 to 7.4)	0.02	21.2 (16.3 to 26.1)	*P* <.001	25.0 (19.7 to 30.4)	*P* <.001
Women	20-74	Skinfold	11.3 (8.5 to 14.1)	*P* <.001	8.1 (5.0 to 11.3)	*P* <.001	19.5 (16.5 to 22.4)	*P* <.001
		BMI	-0.1 (-1.9 to 1.7)	0.45	15.5 (13.0 to 17.9)	*P* <.001	15.4 (12.7 to 18.0)	*P* <.001
	20-39	Skinfold	12.1 (8.5 to 15.8)	*P* <.001	9.4 (4.7 to 14.2)	*P* <.001	21.6 (17.1 to 26.0)	*P* <.001
		BMI	2.1 (-0.3 to 4.4)	0.04	13.5 (9.7 to 17.3)	*P* <.001	15.6 (11.8 to 19.3)	*P* <.001
	40-59	Skinfold	13.6 (10.0 to 17.2)	*P* <.001	7.3 (3.2 to 11.4)	*P* <.001	20.9 (16.3 to 25.4)	*P* <.001
		BMI	0.4 (-2.9 to 3.7)	0.40	16.9 (12.6 to 21.3)	*P* <.001	17.4 (13.0 to 21.7)	*P* <.001
	60-74	Skinfold	3.5 (-2.1 to 9.0)	0.11	6.7 (1.6 to 11.9)	0.01	10.2 (3.8 to 16.7)	*P* <.001
		BMI	-7.3 (-12.0 to -2.5)	*P* <.001	17.0 (11.9 to 22.1)	*P* <.001	9.8 (3.5 to 16.0)	*P* <.001

*NHES indicates National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey; and CI, confidence interval.
†Estimated prevalences for ages 20-74 years were age-standardized by the direct method to the 2000 Census population using age groups 20-39, 40-59, and 60-74 years.

Figure 1

Trend in Youth Obesity Measured Using Skinfold Thickness and Body Mass Index

NHES Cycle 3 (1966-70) to NHANES 2005-06



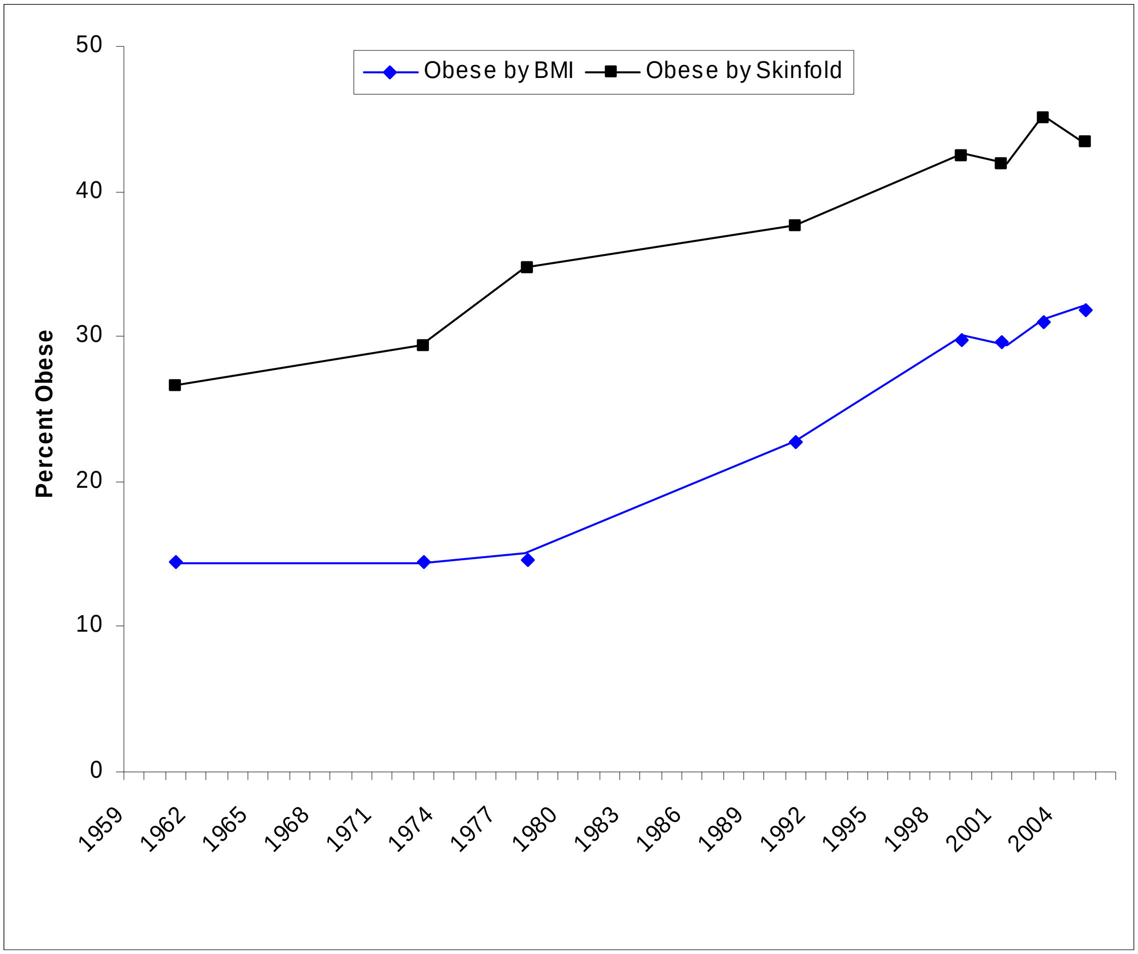
Notes:

1) Data points are located at mid-point of surveys NHES cycle 3 (1966-70), NHANES I (1971-75), NHANES II (1976-80), and NHANES III (1988-94). For the following NHANES Continuous surveys, data points are placed at the first of the two years of the surveys: NHANES 1999-2000, NHANES 2001-02, NHANES 2003-04, NHANES 2005-06.
2) Obesity rates are age- and sex-adjusted based on population counts in the 2000 Census.

Figure 2

Trend in Adult Obesity Measured Using Skinfold Thickness and Body Mass Index

NHES Cycle 1 (1959-1962) to NHANES 2005-06



Notes:

1) Data points are located at mid-point of surveys NHES I (1959-62), NHANES I (1971-75), NHANES II (1976-80), and NHANES III (1988-94). For the following NHANES Continuous surveys, data points are placed at the first of the two years of the surveys: NHANES 1999-2000, NHANES 2001-02, NHANES 2003-04, NHANES 2005-06.
2) Obesity rates are age- and sex-adjusted based on population counts in the 2000 Census.