

# The Geographic Distribution of Obesity in the US and the Potential Regional Differences in Misreporting of Obesity

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**Objective:** State-level estimates of obesity based on self-reported height and weight suggest a geographic pattern of greater obesity in the Southeastern US; however, the reliability of the ranking among these estimates assumes errors in self-reporting of height and weight are unrelated to geographic region.

**Design and Methods:** Regional and state-level prevalence of obesity (body mass index  $\geq 30$  kg m<sup>-2</sup>) for non-Hispanic black and white participants aged 45 and over were estimated from multiple sources: (1) self-reported from the behavioral risk factor surveillance system (BRFSS 2003-2006) ( $n = 677,425$ ), (2) self-reported and direct measures from the National Health and Nutrition Examination Study (NHANES 2003-2008) ( $n = 6,615$  and  $6,138$ , respectively), and (3) direct measures from the REasons for Geographic and Racial Differences in Stroke (REGARDS 2003-2007) study ( $n = 30,239$ ).

**Results:** Data from BRFSS suggest that the highest prevalence of obesity is in the East South Central Census division; however, direct measures suggest higher prevalence in the West North Central and East North Central Census divisions. The regions relative ranking of obesity prevalence differs substantially between self-reported and directly measured height and weight.

**Conclusions:** Geographic patterns in the prevalence of obesity based on self-reported height and weight may be misleading, and have implications for current policy proposals.

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## Introduction

Temporal changes in the prevalence of obesity at the state level are well documented using data from the behavioral risk factor surveillance system (BRFSS) (see <http://www.cdc.gov/obesity/data/trends.html>) (1). The BRFSS is the largest on-going telephone survey in the world, and interviews over 350,000 participants annually. The large sample size of BRFSS has allowed the survey to provide the evidence of geographic variations of obesity in the US, with precise state-level estimates for each year since the 1980s. Figure 1 shows three selected years of these maps, where in 1994 (one of the first years with data available for most states) the highest prevalence of obesity was 15-19% and was clustered in the southeast and west central regions. By 2002, the highest obesity estimates were between 25 and 29% in Mississippi, Alabama, and West

Virginia. By 2010, the prevalence continued to increase to estimates of over 30% across the south and in Michigan (1).

While the motivation for presenting these maps is likely to highlight the temporal change in obesity prevalence, their presentation at the state level naturally draws attention to geographic variations in obesity prevalence, and specifically to the consistently higher prevalence of obesity in the southern regions of the US. This higher prevalence of obesity in the Southern region has been persistent over the entire observation period, and it has appeared particularly higher in the south central states of Mississippi, Alabama, and Tennessee.

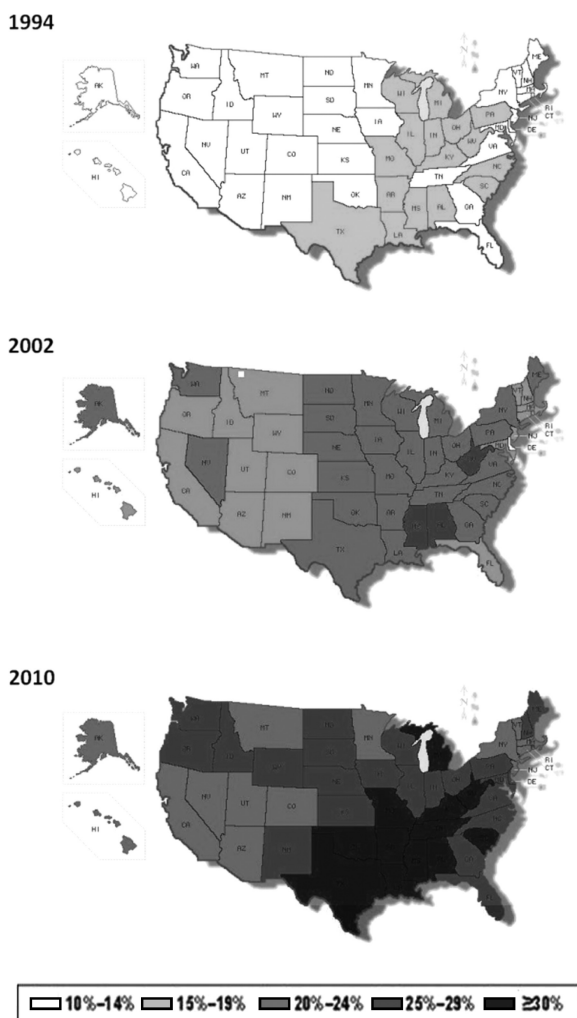
Underlying these data is a widely recognized issue related to the validity of self-reported height and weight, with estimates of up to

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**FIGURE 1** BRFSS data showing the percent of population that is obese ( $\geq 30$  kg  $m^{-2}$ ) at the state level: 1994, 2002, and 2010.

30-40% misclassification of obesity from self-report (2). BRFSS relies on self-reported height and weight data, and compared to measured height and weight data from the National Health and Nutrition Examination Survey (NHANES), BRFSS underestimated the overall national obesity prevalence by nearly 10% (3). Of note, very little has been reported about geographic variations in self-report biases related to weight, which would affect the geographic pattern of obesity. The possibility of a geographic difference in the magnitude of the biases of self-reported height and weight [and the resulting body mass index (BMI) calculation] was originally raised by the authors in observing the lack of concordance between the state-level average BMI calculated from self-reported height and weight from the BRFSS and the state-level average BMI calculated from directly measured height and weight in the REasons for Geographic And Racial Differences in Stroke (REGARDS) study. REGARDS is a US national cohort study that enrolled 30,239 non-Hispanic blacks and whites over the age of 45 during 2003-2007 (4). Therefore, the authors sought additional sources of data to determine potential regional variations in the prevalence of obesity.

To study this question, we have contrasted the prevalence of obesity calculated from self-reported height and weight from the BRFSS to the prevalence of obesity calculated from direct measurement of height and weight from other national cohort studies. The NHANES includes fewer participants than BRFSS, but is nationally representative and includes both self-reported and measured height and weight. The REGARDS study has a sample size intermediate between BRFSS and NHANES. We used data from the BRFSS, NHANES and the REGARDS study to examine how regional variations in self-reporting of height and weight impact US subregional estimates of the prevalence of obesity.

## Methods

### BRFSS 2003-2006

BRFSS is a center for disease control and prevention (CDC) sponsored national telephone survey that provides state-level prevalence estimates of selected health-related behaviors and other factors that are associated with health outcomes. Surveys were performed using standardized telephone procedures by the health agencies in the participating states to interview one resident over 18 years of age from eligible households. The median state response rates were 53.2% in 2003, 51.4% in 2004, 51.1% in 2005, and 51.4% in 2006. Height and weight were obtained from residents' answers to the questions "About how tall are you without shoes?" and "About how much do you weigh without shoes?" (5).

To assess prevalence of obesity for approximately the same time-frame across all the studies, we combined four consecutive years of data from 2003 to 2006 to generate BRFSS-estimated obesity prevalence. For analysis, we included only Non-Hispanic blacks and whites over the age of 45, to be comparable to REGARDS (hereafter called blacks and whites).

### NHANES 2003-2008

NHANES is a continuous survey conducted by the National Center for Health Statistics to collect data on the health status of the US residents. NHANES was based on a complex, multistage probability sampling design in which selection was based on counties, blocks, households, and persons within households. We selected 6 years, 2003-2008, of continuous NHANES data to provide sufficient sample for precise estimation of prevalence of obesity and to be approximately concordant with the REGARDS enrollment period and with selected BRFSS data. The average response rates for household interviews among NHANES adults were 72.3% in 2003-2004, 73.0% in 2005-2006, and 72.6% in 2007-2008. For examinations, the average response rates were 68.1% in 2003-2004, 69.8% in 2005-2006, and 69.6% in 2007-2008. Demographic information such as age and sex was taken from the Family Questionnaire during an in-home interview. NHANES collected self-reported height and weight with the questions "How tall are you without shoes?" and "How much do you weigh without clothes or shoes?" at the in-home visits. Health examinations including anthropometrics were performed by trained health technicians using standardized procedures at Mobile Examination Centers. Height was measured using an electronic stadiometer and weight was measured using a digital scale (6). To be comparable to REGARDS, we included only black and white adults over the age of 45.

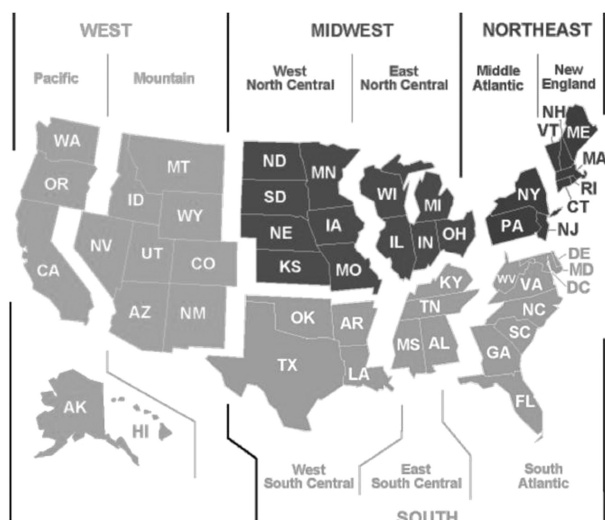


FIGURE 2 US census regions and divisions.

## REGARDS 2003-2007

REGARDS is an NIH-funded population-based prospective cohort study among 30,239 black and white community-dwelling adults aged 45 years and older, who resided in the 48 continental United States at time of enrollment between 2003 and 2007. REGARDS was designed to randomly select, with approximately equal representation, whites and blacks, men and women, with oversampling from the stroke belt region in the southeastern US (specifically, the states of Alabama, Arkansas, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee). Potential participants were selected from commercially available lists, and contacted by an introductory letter followed by telephone contact, and 49% of eligible individuals agreed to participate. Interview information including demographic information, health status, health behaviors and medical history elements were obtained using computer-assisted telephone interviews. Participants subsequently had in-home visits to obtain physical measurements including height and weight using standardized methods. Height was measured using an electronic stadiometer and weight was measured using a digital scale (4). Study design details and a US map showing distribution of participants' state of residence at time of enrollment is provided elsewhere.

## Estimates of obesity

For all studies, BMI was calculated as weight in kilograms divided by height in meters squared and rounded to the nearest tenth. Obesity was defined as BMI of 30.0 or higher according to current recommendations (7).

## Data analysis

NHANES restrictions on the use of data include a requirement that data cannot be reported on a geographic basis smaller than US Census divisions (see Figure 2), requiring most of the comparisons in this report to be made at that level. The goal of analyses was to produce estimates (with appropriate standard errors) of the proportion of obese individuals within the black and white population within a region

(states for some analyses, census regions for most analyses). Age-race-sex specific sampling weights are available for all three studies, allowing a population estimate to be produced where each participant is weight to reflect the number of people in the population that he or she represents. Because the weights are age-race-sex specific, the estimate of the proportion obese in the population is produced (with appropriate estimate of the standard error) adjusting for the distribution of age-race-sex within each study. SAS-callable SUDAAN was used to perform weighted statistical analysis for all three data sources.

For consistency with other CDC reports, we limited the analysis to persons <500 pounds in weight and <7 feet in height for all three studies. In addition, to be comparable to REGARDS (that included only white and black participants above age 45), analysis in BRFSS and NHANES was also restricted to white and black participants above age 45. For state comparisons between BRFSS and REGARDS, comparisons were only made with the 25 states that had at least 200 REGARDS participants.

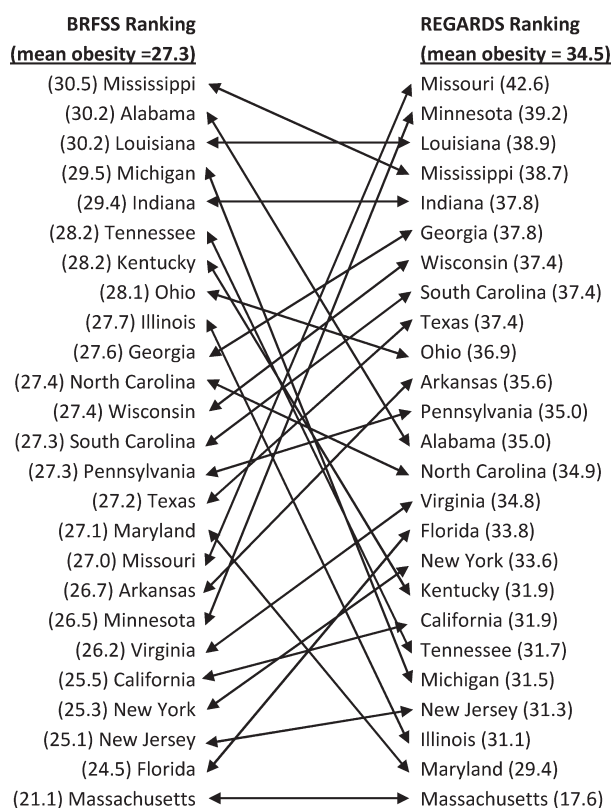
## Results

### Sample sizes

BRFSS data included 677,425 participants (92.7% white and 7.3% black) with self-reported height and weight. The NHANES data included 6,615 participants (88.5% white and 11.5% black) with self-reported height and weight and 6,138 participants (73.3% white and 26.7% black) with measured height and weight. The REGARDS data used in this analysis included 30,183 participants (58.5% white and 41.5% black) with measured height and weight.

### Differences in state-level average

Figure 3 demonstrates the (lack of) agreement in the relative rank between the self-reported (BRFSS) obesity estimates and the directly measured (REGARDS) obesity estimates at the state level. Not surprisingly, obesity prevalence was lower in the self-reported BRFSS study (average = 27.3%) than from direct measures taken in the REGARDS study (average = 34.5%); however, the focus of this analysis is whether states have the same relative ranking from self-reported and directly measured BMI. The Spearman correlation between obesity levels in REGARDS and BRFSS was only 0.30, an association that did not reach a level of statistical significance ( $P = 0.15$ ). There were states with precisely the same ranking as indicated by flat arrows, specifically Massachusetts (most lean state in both surveys), Louisiana (3rd most obese in both surveys), and Indiana (5th most obese in both surveys). In addition, selected other states had approximately the same ranking, for example Mississippi was the most obese state in BRFSS and the 4th most obese in REGARDS, Ohio was the 8th most obese state in BRFSS and the 10th most obese in REGARDS, and New Jersey was the 23rd most obese in BRFSS and the 22nd most obese in REGARDS. However, there were many states with different prevalence estimates between the two data sources. Using measured data from REGARDS, the non-Southern states of Missouri and Minnesota in the East North Central Census Division had the highest obesity estimates but were ranked 17th and 19th among the 25 states according to BRFSS. Conversely, the southern states of Mississippi and Alabama in the East South Central Census Division had the highest prevalence of obesity in BRFSS but were ranked 4th and 13th by REGARDS.



**FIGURE 3** State ranking for age-sex adjusted prevalence of obesity (with % obese), listed from the most obese to least obese by BRFSS and REGARDS. For example, based on BRFSS Mississippi had the highest proportion of residents with obesity with 30.5%; however, based on REGARDS the proportion of obesity in Mississippi was 4th highest with 38.7%. States with similar rankings in the two studies will have relatively flat lines (e.g., Louisiana, which is third in both studies), while states with discordant rankings will have lines with steep slopes (e.g., Missouri, which is 17th in BRFSS and 1st in REGARDS). Data shown for all states with at least 200 REGARDS participants.

## Obesity prevalence estimates by US census division

Table 1 provides the estimated obesity prevalence rates for the nine US census divisions from the four data sources (BRFSS and NHANES self-reported height and weight, and NHANES and REGARDS measured height and weight). The prevalence rates derived using BRFSS data showed two divisions with a similarly low obesity prevalence (21.6% for New England and 21.9% for Mountain), and then a clustering of the other regions between prevalence of 25.4% (Pacific) and 29.1% (East South Central Region). For the most part, the other data sources resulted in strikingly higher prevalence rates, with the highest prevalence topping 41% (REGARDS—West North Central) and only two divisions with prevalence below 25% using measured data (NHANES—Mountain and REGARDS—New England). Furthermore, there the difference in the mean prevalence of obesity between the studies, showing 5.2% higher average (across the census divisions) for the self-reported NHANES data than the BRFSS data. The prevalence of obesity using the measured data from NHANES was 4.1% higher and from REGARDS was 3.9% higher than self-reported NHANES data, and 9.3 and 9.1% higher than the BRFSS-derived estimates, respectively (results not shown).

Figure 4(A-C) provides the pairwise comparisons of the mean (with 95% confidence intervals) obesity prevalence estimates for the Census divisions for the BRFSS, NHANES direct measures, and REGARDS direct measures. As seen in the first row of panels (Figure 4A and B) contrasting NHANES and REGARDS directly measured prevalence estimates with those the BRFSS self-report, the self-reported BRFSS data provide consistently lower estimates (i.e., the observations are consistently above the line of equivalence). BRFSS-derived estimates were also “bunched” with less variation than that observed in the estimates from NHANES and REGARDS. In addition, there is a substantial lack of concordance in the ranking of the Divisions, where (for example) the East South Central (ESC) region is highest for BRFSS (i.e., the rightmost point in both graphs) but is intermediate or low in both NHANES and REGARDS (i.e., not the highest point on either graph). Finally, the bottom right panel demonstrates high level of concordance between the estimates of obesity prevalence using the directly measured heights and weights from NHANES and the REGARDS study.

## Discussion

We observed substantial discordance in the geographic ranking of the prevalence of self-reported obesity as assessed by BRFSS compared with other national data sources using directly measured heights and weights. The agreement of directly measured NHANES with REGARDS, and the similarity of the discordance in the pattern of directly measured NHANES-versus-BRFSS and the REGARDS-versus-BRFSS suggests that the geographic pattern of obesity observed using BRFSS data should be interpreted with some caution. For example, the East South Central division (Alabama, Mississippi, Tennessee, and Kentucky) had the highest prevalence of obesity according to BRFSS data, but this division had the next to lowest prevalence using NHANES measured data, and only the 5th (of eight divisions) highest prevalence using REGARDS data. Conversely, the West North Central division (North Dakota, South Dakota, Nebraska, Kansas, Missouri, Iowa, and Minnesota) had the highest prevalence of obesity according to REGARDS data and the second highest prevalence using directly measured NHANES data, but only the 4th highest prevalence based on BRFSS data. There were, however, divisions with good agreement across all data sources. For example, the Pacific and the Mountain division had among the lowest prevalence of obesity according to all four sources. (New England Division was also but data were only available for BRFSS and REGARDS.) Collectively, the concordance of REGARDS and NHANES direct measurement, and their discordance with BRFSS, may suggest that the impression of the southeastern US as being the most obese region may be a result of differential reporting bias present in the BRFSS.

It is not surprising that obesity prevalence estimates based on self-reported height and weight were substantially lower than those based on direct measurement. Self-reported weight is well known to be systematically underreported, and to a lesser extent height may be systemically over reported, resulting in lower BMI estimates (2). It is important to note that this bias implies that the BRFSS-based maps showing the stunning obesity epidemic are likely substantial underestimates of the problem. Our primary focus in this report was to assess if there are geographic variations in the magnitude of the biases in obesity estimates, and we found evidence that such variations do in fact appear to be present. Our study was not able to



**TABLE 1** US census division sample sizes (unweighted), obesity estimates (weighted mean %  $\pm$  standard error), and prevalence ranking (ascending order from most obese to least)

| US census division | Obesity prevalence based on self-reported height and weight |                                  |      |          |                                  |      | Obesity prevalence based on measured height and weight |                                  |      |          |                                  |      |
|--------------------|---|----------------------------------|------|----------|----------------------------------|------|--|----------------------------------|------|----------|----------------------------------|------|
|                    | BRFSS   |                                  |      | NHANES   |                                  |      | NHANES   |                                  |      | REGARDS  |                                  |      |
|                    | <i>N</i>  | Prevalence estimate (%) $\pm$ SE | Rank | <i>N</i> | Prevalence estimate (%) $\pm$ SE | Rank | <i>N</i>   | Prevalence estimate (%) $\pm$ SE | Rank | <i>N</i> | Prevalence estimate (%) $\pm$ SE | Rank |
| New England        | 75852   | 21.6 $\pm$ 0.2                   | 9    | 188      | N/A                              | N/A  | 176  | N/A                              | N/A  | 405      | 22.9 $\pm$ 2.8                   | 9    |
| Middle Atlantic    | 61007   | 26.0 $\pm$ 0.3                   | 6    | 1132     | 32.9 $\pm$ 1.0                   | 4    | 1035   | 37.6 $\pm$ 1.0                   | 3    | 1748     | 33.9 $\pm$ 2.1                   | 6    |
| E. North Central   | 61570   | 28.4 $\pm$ 0.3                   | 2    | 1029     | 33.5 $\pm$ 2.1                   | 2    | 949  | 40.2 $\pm$ 1.8                   | 1    | 3681     | 34.6 $\pm$ 1.4                   | 3    |
| W. North Central   | 88886   | 26.8 $\pm$ 0.2                   | 4    | 649      | 36.5 $\pm$ 2.4                   | 1    | 596  | 39.8 $\pm$ 3.3                   | 2    | 1009     | 41.3 $\pm$ 2.5                   | 1    |
| South Atlantic     | 130718  | 26.4 $\pm$ 0.2                   | 5    | 1698     | 33.4 $\pm$ 1.4                   | 3    | 1581   | 37.1 $\pm$ 1.2                   | 4    | 12056    | 34.4 $\pm$ 1.1                   | 4    |
| E. South Central   | 44033   | 29.1 $\pm$ 0.3                   | 1    | 324      | 29.7 $\pm$ 3.0                   | 6    | 306  | 31.3 $\pm$ 3.6                   | 7    | 4376     | 34.3 $\pm$ 1.3                   | 5    |
| W. South Central   | 54631   | 27.5 $\pm$ 0.4                   | 3    | 507      | 32.2 $\pm$ 2.9                   | 5    | 472  | 37.1 $\pm$ 2.2                   | 5    | 3955     | 37.4 $\pm$ 1.6                   | 2    |
| Mountain           | 80384   | 21.9 $\pm$ 0.3                   | 8    | 419      | 20.3 $\pm$ 1.6                   | 8    | 396  | 22.8 $\pm$ 1.7                   | 8    | 390      | 30.2 $\pm$ 3.2                   | 8    |
| Pacific            | 80344   | 25.4 $\pm$ 0.4                   | 7    | 669      | 28.4 $\pm$ 3.1                   | 7    | 627  | 33.6 $\pm$ 4.1                   | 6    | 2563     | 31.5 $\pm$ 1.5                   | 7    |

elucidate why these geographic variations in the magnitude of these biases exist, but we speculate that the lower level of social stigma associated with obesity in the Southeastern US may make it more socially acceptable to report true weights.

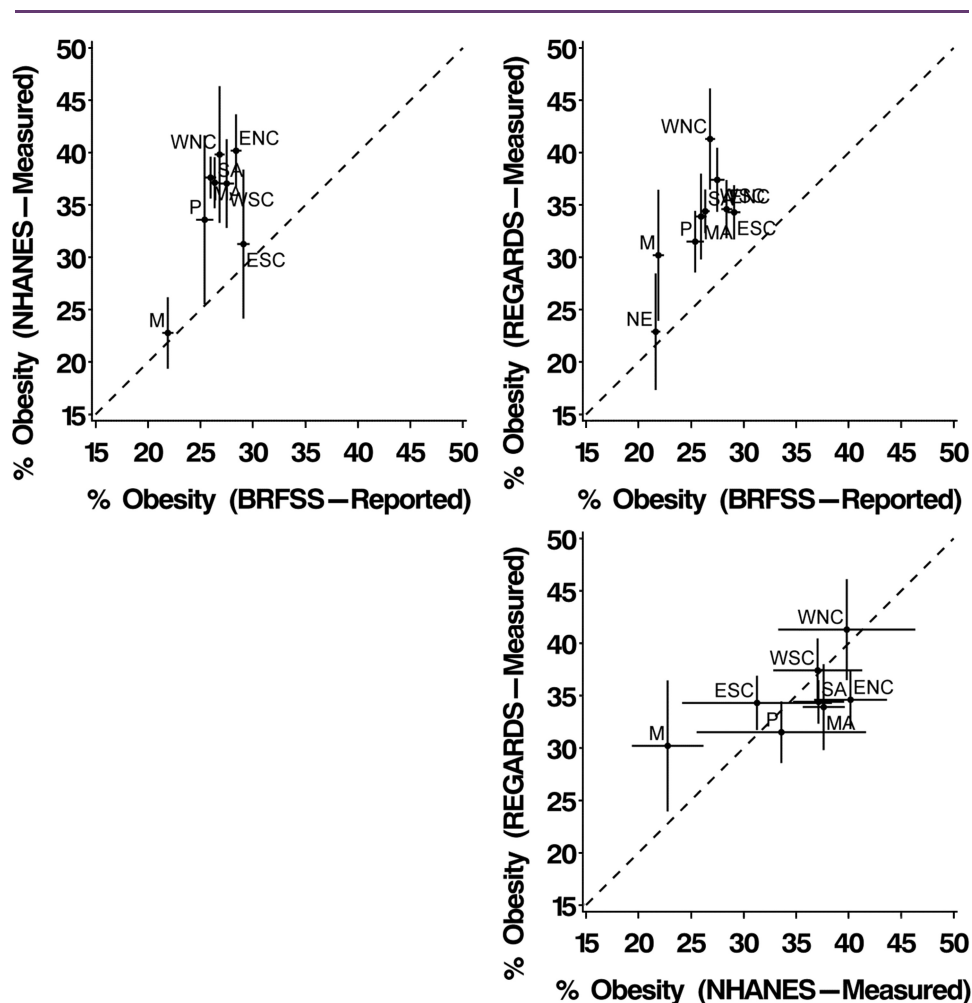
It is also worth noting that the magnitude of bias between self-reported NHANES data and either directly measured NHANES or REGARDS data was smaller than between BRFSS and either directly measured sources. Although it is possible that this smaller difference could be attributed to the NHANES participants either being aware that that direct measures were about to be made, or in some cases, measurement had recently occurred, as interview/exam order is not consistent in NHANES. That NHANES had a more valid reporting of weight than BRFSS is also supported by the greater similarity between NHANES self-reported and direct measures.

These findings are important for several reasons. For example, the recent Institute of Medicine (IOM) report on childhood obesity calls for a focus of nutrition and physical activity programs "... particularly in states with the highest prevalence of childhood obesity." While the findings herein focus on adult rather than childhood obesity, the IOM has recommended differential allocation of federal funding on the basis of geographic differences in the prevalence of obesity, highlighting the importance of the validity of obesity prevalence estimates (8).

While we are suggesting that geographic differences in the reliability of self-reported height and weight could confound the interpretation of geographic variations in the prevalence of obesity, we did not study temporal changes in these biases. If these biases are stable over time within region, the large sample size of the BRFSS may be well suited to monitor temporal changes within states or regions that can inform policy planning, with the caveat that self-reported height and weight likely underestimate the true prevalence of obesity by

~10%. However, these data suggest BRFSS may not be reliable for making comparisons among states or regions.

There are strengths and limitations to this study. While the sample size of BRFSS ( $n = 677,425$ ) provides remarkably stable estimates at the divisional (and state) levels, the smaller sample sizes for REGARDS ( $n = 30,183$ ), self-reported NHANES ( $n = 6,615$ ), and directly measured NHANES ( $n = 6,138$ ) provide less stable estimates. For NHANES, most regions had at least 500 respondents (providing a standard error of the estimated prevalence of obesity with a precision of  $\pm 3\%$ ), while for REGARDS most regions had a sample size of at least 2,500 participants (providing an estimate of the prevalence of obesity with a precision of  $\pm 1.5\%$ ). The lower precision in NHANES and REGARDS may contribute to the larger variation between divisions; however, the sample size for these studies provided a standard error that was not substantially smaller than the observed differences in obesity rates among the divisions. Thus, while BRFSS can reliably detect differences in the prevalence of obesity among the divisions, the specific ranking of obesity prevalence for the divisions is estimated by REGARDS and BRFSS with less confidence. This concern is somewhat mediated by the following observations: (1) for both NHANES and REGARDS, the range of obesity prevalence estimates across the divisions is at least 15%, making estimations of rankings with standard errors of  $\pm 3\%$  in NHANES and  $\pm 1.5$  in REGARDS reasonable, and (2) agreement between the directly measured NHANES and REGARDS suggests the validity of both sets of estimates. In addition, while the response rates for all three studies were similar to many other population-based studies, it is possible that those responding to the study were not representative of the general population. While there is no reason to suspect that nonresponse is related to obesity, it is possible that nonresponse could contribute to misleading results. In addition, there could be differential misreporting of obesity levels by the age, race or sex of the participant. While these studies are sizable, the number of participants within regions for NHANES (and only to a somewhat lesser extent



**FIGURE 4** Comparisons of obesity prevalence estimates for Non-Hispanic black and white adults over 45 years of age from three national datasets (NHANES-measured, BRFSS, and REGARDS) among the Census divisions of the United States. Data are shown for the estimated prevalence (point) and 95% confidence interval by each study (line on either side, or above and below, each estimate). Abbreviations: MA = Middle Atlantic, ENC = East North Central, WNC = West North Central, SA = South Atlantic, ESC = East South Central, WSC = West South Central, M = Mountain, and P = Pacific (NHANES sample size not sufficient for estimation in NE = New England).

REGARDS) would not allow stratified analysis to assess if differential misreporting with demographic strata is also present.

Should a ranking of states or regions be important to inform policy decisions, more stable estimates could potentially be produced by pooling the data from NHANES and REGARDS (and potentially other sources) to provide both valid and the most stable estimates available; however, restrictions on the use of NHANES data would have to be relaxed to perform these analyses. For the purposes of this article, limitations on use of the NHANES data required the analysis to be performed at the census division level, not allowing estimates from the New England division that had a sample size of <190 participants. Even for REGARDS, the Mountain Region with eight states (Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico) had only 390 participants. With the REGARDS sample size being approximately five times larger than NHANES, REGARDS still only has 25 states with at least 200 par-

ticipants, the CDC limitation for the minimum number of participants to provide estimates.

In conclusion, while the sample size of BRFSS provides precise regional estimates of obesity prevalence that are very valuable for tracking temporal changes in obesity rates, our study suggests that there may be geographic differences in the magnitude of the well-known bias of self-reported height and weight that limits the use of these estimates for regional comparisons.<sup>9</sup>

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