ORIGINAL ARTICLE

Fitness adjusted racial disparities in central adiposity among women in the USA using quantile regression

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Summary

Objective

This study comprehensively explores racial/ethnic disparities in waist circumference (WC) after adjusting for cardiorespiratory fitness (CRF), among both adult and adolescent women, across WC percentiles.

Methods

Analysis was conducted using data from the 1999 to 2004 National Health and Nutrition Examination Survey. Female participants (n = 3,977) aged 12–49 years with complete data on CRF, height, weight and WC were included. Quantile regression models, stratified by age groups (12–15, 16–19 and 20–49 years), were used to assess the association between WC and race/ethnicity adjusting for CRF, height and age across WC percentiles (10th, 25th, 50th, 75th, 90th and 95th).

Results

For non-Hispanic (NH) Black, in both the 16–19 and 20–49 years age groups, estimated WC was significantly greater than for NH White across percentiles above the median with estimates ranging from 5.2 to 11.5 cm. For Mexican Americans, in all age groups, estimated WC tended to be significantly greater than for NH White particularly for middle percentiles (50th and 75th) with point estimates ranging from 1.9 to 8.4 cm.

Conclusions

Significant disparities in WC between NH Black and Mexican women, as compared to NH White, remain even after adjustment for CRF. The magnitude of the disparities associated with race/ethnicity differs across WC percentiles and age groups.

Keywords: Cardiorespiratory fitness, obesity, quantile regression, racial disparities.

Introduction

Minority racial/ethnic groups, such as Black and Mexican Americans, experience a disproportionately larger burden of disability, morbidity and premature death as compared with White Americans (1). Central obesity, in particular, is a major health problem in the USA and among one of the many health outcomes for which substantial racial disparities exist (2). Specifically, disparities in central adiposity and the prevalence of abdominal obesity (3) have been reported among female race/ethnicity subgroups (4,5). Evidence suggests that non-Hispanic (NH) Black and Mexican American women possess significantly larger waist circumferences (WC) than NH White women. More alarming are recent reports that disparities in WC among female race/ethnicity groups have widened in recent years (6). For instance, while WC was observed to increase among all female race/ethnicity groups, the upward shift in the WC distribution was much larger among NH Black women. Given the poor cardiometabolic health outcomes related to augmented levels of central adiposity (e.g. type II diabetes and non-alcoholic fatty liver disease) (7–9), the identification of factors that explain, in part, the racial/ethnic disparities in WC is of great public health relevance.

Numerous studies have documented and evaluated racial/ethnic disparities in adiposity (10). However, the majority of studies have limited their assessment to comparing the probability of reaching some unadjusted cut-point intended to indicate an unhealthy level of adiposity (such as BMI of 30 kg m^{-2}) or making inference based solely on average adiposity levels. Few studies have comprehensively examined racial disparities in adiposity across the entire distribution of the adiposity measure. This is of particular importance as a number of previous studies suggest that associations between adiposity and several other important predictors, such as age and cardiorespiratory fitness (CRF), vary across the distribution of the adiposity measure and therefore are not adequately described by techniques focused only on a part of the adiposity distribution (i.e. comparing probabilities of being obese between groups) or comparing mean values (11,12). Furthermore, the few studies to date assessing racial/ethnic disparities across the WC distribution failed to account for CRF despite considerable documentation of its association with WC and race/ethnicity. In a recent study, moderate-to-high levels of CRF were found to be associated with lower WC (12). Importantly, this study found that higher levels of fitness exhibited the greatest reductions in WC among individuals that were the most centrally obese (>90th percentile). Given that the documented upward shifts in the WC distribution have been most accelerated at the upper tails, the achievement of higher CRF appears to be critically important for this subgroup. Similarly, racial/ethnic disparities in CRF have also been documented. Specifically, NH Black women have been suggested to have lower levels of CRF compared with Mexican Americans and NH White counterparts (13–16). Therefore, the purpose of this study is to comprehensively explore racial/ethnic disparities in WC after adjusting for CRF, among both adult and adolescent women, using quantile regression.

Methods

Survey design and study population

This study used data from the 1999 to 2004 cycles of the national health and nutrition examination survey (NHANES), a series of cross-sectional population-level surveys from a nationally representative sample of non-institutionalized US residents (17). For the purpose of this study, only female participants aged 12 to 49 years were included in the analyses given the age restrictions of cardiovascular fitness test and the interest in the female subpopulation.

For the cardiovascular fitness test, 14,417 participants (men and women) were randomly selected to participate. Of these, 2,626 were excluded from the test because of various reasons (e.g. physical limitations, cardiovascular and/or respiratory conditions). Pregnant women (>12 weeks) were also excluded from the cardiovascular fitness test. After these exclusions, 11,093 participants were eligible for the cardiovascular fitness test, which was not completed by 2,769 participants because of various reasons (e.g. refusal, technical issue). As a result, maximal oxygen consumption was estimated for 8,234 eligible participants (18). Because this study focused solely on women, only 3,980 of the eligible participants were included. Of these, three female participants had missing anthropometric data (i.e. height and/or weight), resulting in a final analytic sample of 3,977 female participants aged 12 to 49 years.

Race and ethnicity

The race and ethnicity of the participants were assessed via questionnaire. For race, participants were asked to select a racial group they most identified with (i.e. American Indian or Alaskan Native, Asian, Black or African–American, Native Hawaiian or Pacific Islander, White or Other). For ethnicity, participants were asked to choose a group that best represented their national origin or ancestry (i.e. Mexican American/Mexican, Other Hispanic or Latino, both Mexican and Other Hispanic, not Hispanic). Race/ethnic groups were then categorized as per NHANES protocol into the following five groups: NH White (referent group), NH Black, Mexican American, Hispanic and Other. In addition, because the sample sizes for the Hispanic and Other groups are too small to provide reliable estimates, only estimates from the NH White, NH Black and Mexican American groups were interpreted.

Central adiposity – waist circumference

Central adiposity was determined by measuring the WC of participants via NHANES anthropometric protocol ((19)). A measuring tape was used to assess WC, and values were recorded to the nearest millimetre.

Covariates

Cardiorespiratory fitness was determined by the estimation of maximal oxygen consumption ($\dot{V}O_2$ max) via a submaximal treadmill exercise test. The exercise test employed a four-stage protocol that consisted of a 2-min warm-up stage; two, 3-min exercise stages, followed by a 2-min cool-down stage. Heart rate and blood pressure were continuously monitored throughout the testing period, and maximal oxygen consumption was estimated via linear extrapolation (18). $\dot{V}O_2$ max was expressed relative to body weight as millilitres of oxygen per kilogramme of body weight per minute (mL O_2 kg^{-1} min^{-1}). Other potential covariates with established physiological relationships with the primary independent and dependent variables were age (years), height (m) and weight (kg). Height and weight were assessed via the NHANES anthropometric manual using a fixed stadiometer with vertical backboard and movable headboard and a Toledo digital scale, respectively.

Statistical analysis

The statistical software used for all analyses was 'R' version 3.2.2. All statistical analyses including descriptive statistics (frequencies, means and standard deviations) and regression models were stratified according to age (12–15, 16–19 and 20–49 years of age). Quantile regression was used to assess the associations between race/ethnicity and WC, treated as outcome variables. Quantile regression has the advantage of allowing the examination of relationships across the entire distribution of the outcome, rather than only at the center, allowing for a more complete description of the association between racial/ethnicity and the outcome of interest (WC). For all quantile regression analyses, adjusted percentiles (10th, 25th, 50th, 75th, 90th and 95th) of the outcome were estimated using the 'R' survey package extended to accommodate quantile regression and account for the complex NHANES survey design with standard errors being calculated using replicate weights (20). Quantile regression coefficients are interpreted similarly to mean regression coefficients except that a quantile regression coefficient indicates the change in the outcome variable at the modeled percentile, not the mean change. For example, consider a categorical predictor such as race/ethnicity with the following three levels; NH Black, Mexican and NH White (used as the referent level) in a quantile regression model with WC as the outcome. A coefficient estimate of 9.0 for NH Black in the quantile regression model for the 90th percentile would indicate that the 90th percentile of WC is estimated to be 9.0 cm greater for NH Black as compared with NH White after controlling for other covariates in the regression model.

For the quantile regression analyses, WC (cm) was treated as the dependent variable. Estimated $\dot{V}O_2$ max (mL O_2 kg^{-1} min^{-1}), age (years), height (m) and race (NH White, NH Black, Mexican American, Hispanic and Other) were included as independent variables in the regression models. In the analysis for women aged 20–49 years, a linear spline with a knot at 40 years was included to account for a potential change in either the magnitude or the direction of the association between the outcome variable and age as women reach middle age.

The inference from this study applies to the non-institutionalized US civilian population from 12–49 years of age without physical limitations or history of cardiovascular disease (i.e. those eligible to take the fitness test). As discussed previously, the majority of item non-response was due to missing $\dot{V}O_2$ max estimates. Data were assumed to be missing at random, and the potential impact of non-response on the regression coefficients for race/ethnicity at the 10th, 50th and 90th percentiles was assessed using multiple imputations using all variables in the quantile regression model via Gibbs sampling. The results from the imputation (not shown) were consistent in both magnitude and significance with results using complete cases and an average difference in the regression coefficients for NH Black of 0.2 cm and an average difference for Mexicans of 0.30 cm. As a result, for simplicity, the results from the complete case analyses are presented. In addition, all quantile regression analyses were repeated using weight (kg) in place of WC as the outcome variable.

Results

Demographic characteristics of the participants included in the analysis are presented in Table 1. For both

Table 1 Sample characteristics of NHANES 1999–2004[a] female participants, unweighted means (SD) and proportions (%), stratified by age group

	Age group		
	12 to 15 years (*n* = 1,314)	16 to 19 years (*n* = 1,098)	20 to 49 years (*n* = 1,565)
Age (years)	13.4 (1.1)	17.4 (1.1)	33.4 (8.6)
Race/ethnicity (%)			
NH White	24.4	24.7	47.8
NH Black	32.0	28.7	19.9
Mexican	35.6	36.8	24.6
Weight (kg)	58.8 (15.2)	65.6 (17.0)	72.9 (18.4)
Height (m)	1.6 (0.1)	1.6 (0.1)	1.6 (0.1)
BMI	23.0 (5.3)	25.0 (6.1)	27.6 (6.7)
Waist circumference (cm)	78.2 (12.5)	83.1 (13.8)	89.8 (14.8)
Estimated $\dot{V}O_2$ max (mL O_2 kg min^{-1})	39.3 (8.6)	38.3 (9.1)	36.0 (8.9)

BMI, body mass index; NH, non-Hispanic; NHANES, national health and examination survey.
[a]NHANES 1999–2004 sample weights were not applied, and sample characteristics apply only to those with complete data on the variables listed above.

adolescent age groups, nearly one-quarter were NH White, whereas approximately 50% the female adults were NH White. Average WC in the sample increased across the age groups, 78.2 cm (12 to 15 years), 83.1 cm (16 to 19 years) and 89.8 cm (20 to 49 years). Conversely, estimated maximal oxygen consumption tended to decline with increasing age groups, 39.3, 38.3 and 36.0 mL O_2 kg^{-1} min^{-1}, respectively.

The adjusted quantile regression estimates for the association of race/ethnicity on the 10th, 25th, 50th, 75th, 90th and 95th WC percentiles, for women, stratified by age group, are presented in Table 2. For women aged 12 to 15 years, WC percentiles for Mexican American women tended to be greater than NH Whites, with significant differences found at the 10th, 25th, 50th and 75th adjusted WC percentiles and estimates ranging from 2.0 to 6.1 cm. No significant differences in WC between NH Black and NH White were observed across percentiles for this age group.

For women aged 16 to 19 years, adjusted WC percentiles for Mexican Americans were significantly greater than NH White at the 10th, 50th and 90th percentiles with estimated differences in WC ranging from 2.4 to 8.4 cm. Similarly, WC estimates for NH Black women were significantly greater than for NH White at percentiles greater than the 50th with estimated differences ranging from 5.2 to 11.6 cm.

For women aged 19 years and over, significant estimated differences in WC were found for both Mexican American and NH Black women. Specifically, at the 10th, 25th, 50th and 75th percentiles, Mexican American women had significantly higher WC compared with their NH White counterparts. Significant estimates in WC ranged from 4.3 to 7.6 cm. Likewise, WC estimates for NH Black women were significantly greater than for NH White for all percentiles above the 10th with estimates ranging from 6.1 to 11.5 cm.

The age-stratified estimated differences in WC for the 5th to 95th WC percentiles for NH Black and Mexican American (compared with NH White) from the adjusted quantile regression models are presented in Figures 1 and 2, respectively.

Discussion

The major finding of this study is that significant disparities in central adiposity among NH Black and Mexican American women, as compared with NH White, remain even after adjustment for CRF and the magnitude of these disparities associated with race/ethnicity differ across WC percentiles and age groups.

The presence of disparities in the central adiposity, among NH Black and Mexican American women after the adjustment for CRF, suggests that other factors may be more important in explaining these disparities. While larger WCs among NH Black and Mexican American women have been repeatedly documented in the scientific literature, studies examining the relationship between race/ethnicity and central adiposity using rigorous measurement methods (e.g. MRI and DEXA) reported contrary findings. Specifically, several studies have found that NH Blacks have a smaller amount of visceral fat (i.e. central adiposity) compared with NH White counterparts of the same height and weight (21–23). The striking difference in the findings between these studies may be due to the inclusion of body weight as a covariate,

Table 2 Adjusted estimated differences in WC [cm] (Est.) and 95% confidence intervals (CI) for select waist circumference percentiles among Mexican American and non-Hispanic (NH) Black women aged 12 to 49 years, stratified by age group

	Percentiles											
	10th		25th		50th		75th		90th		95th	
	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI
Race/ethnicity[a] (n = 3,977)												
12–15 years (n = 1,314)												
Mexican American	1.9	(0.1, 3.7)	2.9	(0.9, 4.96)	3.9	(0.8, 7.0)	6.1	(3.0, 9.2)	5.2	(−1.4, 11.8)	3.2	(−3.6, 10.1)
NH Black	−0.98	(−2.6, 0.64)	−0.5	(−2.05, 1.01)	0.4	(−1.87, 2.56)	1.0	(−2.32, 4.40)	2.4	(-3.9, 8.8)	3.5−	(−3.3, 10.2)
16–19 years (n = 1,098)												
Mexican American	2.4	(0.7, 4.1)	2.1	(−0.6, 4.8)	3.7	(0.95, 6.3)	5.2	(1.2, 9.1)	8.4	(3.5, 13.3)	7.6	(−0.5, 15.7)
NH Black	−0.7	(−2.4, 1.1)	−1.1	(−3.5, 1.4)	0.8	(−2.3, 3.97)	5.2	(0.5, 9.95)	9.9	(2.96, 16.9)	11.6	(2.7, 20.6)
19+ years (n = 1,565)												
Mexican American	4.3	(1.5, 7.0)	5.999	(3.8, 8.2)	7.6	(5.3, 9.8)	6.5	(2.6, 10.4)	3.4	(−3.0, 9.8)	4.2	(−3.5, 12.0)
NH Black	3.5	(−0.1, 9.98)	6.1	(3.6, 8.7)	7.4	(5.3, 9.4)	11.5	(8.3, 14.7)	6.8	(1.8, 11.9)	5.4	(1.0, 9.8)

[a]NH White was the reference level for all racial/ethnic comparisons.
Coefficients in bold indicate significant findings at $p < 0.05$.

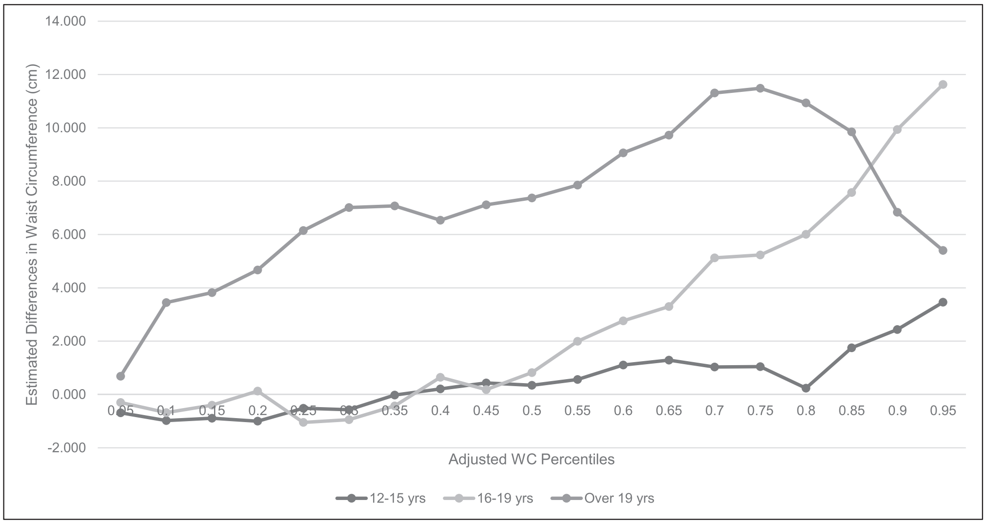

Figure 1 Adjusted estimated differences in waist circumferences (cm) for NH Black women as compared with NH White women across age groups (12–15, 16–19 and over 19 years) across selected percentiles. Estimated differences were derived from the quantile regression model that adjusted for age, age at 40 years (linear spline) and cardiorespiratory fitness and was stratified by age group: 1999–2004 NHANES sample weights were applied.

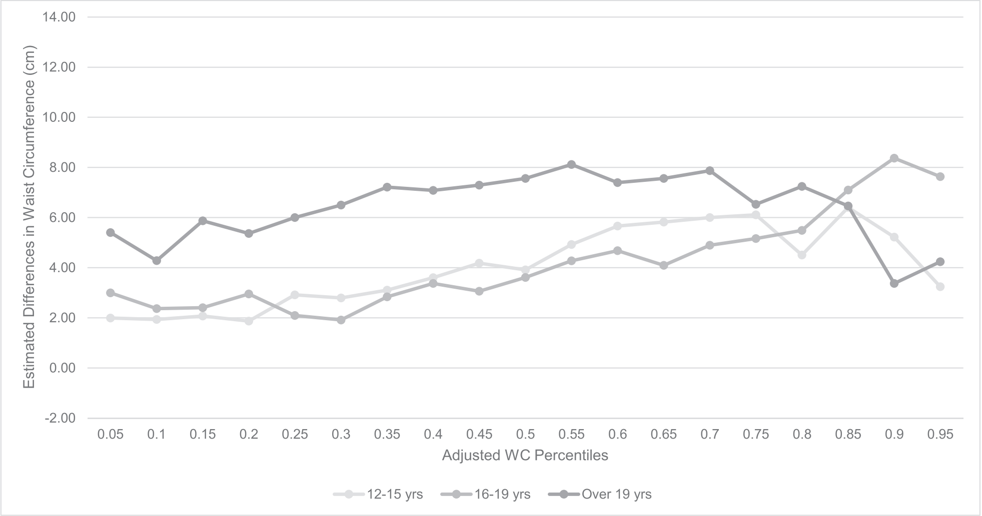

Figure 2 Adjusted estimated differences in waist circumferences (cm) for Mexican women as compared with NH White women across age groups (12–15, 16–19 and over 19 years) across selected percentiles. Estimated differences were derived from the quantile regression model that adjusted for age, age at 40 years (linear spline) and cardiorespiratory fitness and was stratified by age group: 1999–2004 NHANES sample weights were applied.

which was excluded in the present analysis. As such, the contradicting nature of the findings between the current study and others may implicate weight as an important factor in explaining these racial/ethnic disparities in central adiposity.

To explore this apparent contradiction, we performed additional quantile regression analyses using weight (kg) as the outcome variable, in place of WC (Table 3). Results show that for all age groups, NH Black and Mexican American women tended to be significantly heavier compared with NH White counterparts of the same age, fitness level and height, across a majority of weight percentiles. Across all age groups, the magnitude of the estimated differences between NH Black and NH White tended to increase with increasing weight percentiles. Estimated differences in weight range from 2.5 to

Table 3 Adjusted estimated differences in weight [kg] (Est.) and 95% confidence intervals (CI) for select weight percentiles among Mexican American and non-Hispanic (NH) Black women aged 12 to 49 years, stratified by age group

	Percentiles											
	10th		25th		50th		75th		90th		95th	
	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI
Race/ethnicity[a] (*n* = 3,977)												
12–15 years (*n* = 1,314)												
Mexican American	**1.96**	**(0.03, 3.9)**	1.5	(−0.9, 3.95)	**4.1**	**(1.9, 6.3)**	**4.2**	**(0.2, 8.1)**	**8.4**	**(0.95, 15.8)**	6.7	(−1.6, 15.1)
NH Black	**2.5**	**(0.6, 4.4)**	**2.6**	**(0.7, 4.5)**	**3.9**	**(1.7, 5.99)**	**6.3**	**(1.9, 10.6)**	**6.9**	**(0.9, 12.9)**	**11.1**	**(3.3, 18.8)**
16–19 years (*n* = 1,098)												
Mexican American	**2.8**	**(1.4, 4.1)**	2.2	(−0.3, 4.7)	2.2	(−0.7, 5.1)	**6.9**	**(2.5, 11.3)**	**9.0**	**(2.6, 15.5)**	**11.2**	**(1.5, 20.8)**
NH Black	**2.3**	**(0.9, 3.6)**	2.3	(−0.01, 4.6)	**5.1**	**(1.95, 8.3)**	**12.97**	**(7.0, 18.9)**	**13.8**	**(6.4, 21.1)**	**16.7**	**(4.8, 28.6)**
19–49 years (*n* = 1,565)												
Mexican American	**3.4**	**(1.0, 5.8)**	**5.1**	**(2.4, 7.9)**	**6.5**	**(3.9, 8.99)**	**5.7**	**(0.4, 11.1)**	0.9	(−5.6, 7.4)	2.5	(−7.1, 12.1)
NH Black	**4.5**	**(2.2, 6.9)**	**7.8**	**(5.8, 9.9)**	**11.5**	**(8.6, 14.3)**	**12.4**	**(9.0, 15.8)**	**11.4**	**(3.8, 18.9)**	**12.3**	**(3.2, 21.5)**

[a]NH White was the reference level for all racial/ethnic comparisons.
Coefficients in bold indicate significant findings at $p < 0.05$.

11.1 kg, 2.3 to 16.7 kg and 4.5 to 12.3 kg for adolescents (12 to 15 years; 16 to 19 years) and adults (20 to 49 years), respectively. These findings reconcile the results from this current analysis with previous studies comparing central adiposity among women of the same weight and suggest that the augmented levels of central adiposity found among NH Black and Mexican American women relative to NH White women may be attributable to their excess weight. Further, the smaller WCs found among NH Black women compared with NH White women of the same weight (and height), as demonstrated in the previous studies, might suggest that minority women may need to gain a substantial amount of weight to overcome their physiological advantage of less visceral adipose tissue. This speculation is supported by the findings of this study and others documenting increased weight among the NH Black female population (4,24,25).

While many factors may influence weight gain, physical activity (and CRF) and caloric intake are likely the primary determinants and are intricately related. It is well documented that considerable levels of physical activity or high levels of fitness are associated with a healthier weight status, specifically and importantly favourable body composition (i.e. less adipose tissue). This is likely because of the increases in lean body mass, basal metabolic rate and a greater sequestering of nutrient energy to the skeletal muscle tissue resulting in decreased adipogenic nutrient partitioning (i.e. less nutrient energy available to be stored as fat) and decrements in weight (26–28). In this study, differences in WC were estimated between NH Black and Mexican Americans relative to NH White adolescent and adult women with comparable CRF levels. Because an individual must engage in chronic exercise training to maintain or increase their level of CRF, CRF is considered to be a surrogate measure of habitual physical activity of an individual (29,30). Given that physical activity is a primary determinant of weight status and that racial/ethnic disparities in WC persisted after the adjustment of CRF, it may be speculated that the differences in central adiposity found among NH Blacks and Mexican American women may be attributable to caloric intake. Numerous studies have been published in the current literature regarding the role of caloric intake on weight status. A substantial body of literature indicates that diet plays a critical role and that among racial/ethnic minority groups, less 'healthier' foods (e.g. sugar-sweetened beverages, high-calorie foods) (31). In addition, some literature suggests that less 'healthy' food options are made available to low-income areas, typically composed of high minority populations, thus reinforcing the consumption of 'unhealthy diets' (32,33). These findings may explain the increased weight among these subpopulations (34).

While there is an established physiological basis for the role of caloric intake and weight status, albeit it is intricately tied to physical activity, much of the evidence in the human populations regarding this relationship is supported by studies predominantly using self-reported measures of diet. Of considerable concern, the scientific merit of data derived from these measures has been repeatedly refuted in the current literature and is suggested to be inadmissible as scientific evidence (35,36). As a result, it is difficult even to speculate regarding the role of caloric intake as a potential explanatory factor for the differences in weight (or WC) documented in this study found among NH Black and Mexican American women. However, this heavily suggests that future researchers invest in the development of more rigorous (i.e. objective) measures of caloric intake to allow for this relationship and other diet–health relationships to be explored scientifically.

In addition, substantial differences in the trends in the WC disparities across percentiles, age groups and race/ethnicities were also observed. As demonstrated in Figure 1, for the 12–15 years age group, no substantial differences between NH Black and NH White women were observed, while differences in WC between NH Black and NH White for the 16–19 years age group tended to increase with increasing WC percentiles showing significant differences for all WC percentiles greater than 0.65 ranging in magnitude from 5.1 to 11.6 cm. Similarly, for the over 19 years age group, differences in WC between NH Black and NH White tended to be large with all estimated differences above the 20th percentile significant and larger than 5.0 cm. In contrast, differences in WC between Mexican Americans and NH White were more consistent across age groups. A potential explanation for this observation may be that NH Black women tend to reach sexual maturity earlier than their NH White counterparts (37) and consequently may gain more weight and accrue body fat at an earlier age. Previous results, not adjusted for CRF, showed significant differences in mean adiposity by age 12 with these differences growing with age (38). The results from the present study demonstrate that while this racial/ethnic disparity in weight remained across all age groups after adjusting for CRF, significant differences in WC were not observed for the 12–15 years age group. Increased levels of adiposity have been suggested to be a predictor of early onset of menarche. Thus, the racial/ethnic differences found in the older adolescent group may be consequent to an augmented acceleration of fat deposition during maturation induced by elevated levels of adiposity prior to its onset. This potentially suggests that by the age of 16 years, NH Black women, specifically people with obesity, may have already overcome their physiological advantage of lesser storage of visceral adipose tissue, illustrated by the larger WCs found in this study.

There are many strengths to this study that warrant attention. First, this study is the first to assess race/ethnic disparities in central adiposity across WC percentiles after adjusting for CRF. These findings indicate that even after accounting for CRF, racial/ethnic disparities in WCs remained. This suggests that other important factors such as weight may potentially explain these disparities. Second, the use of quantile regression allowed us to comprehensively examine the nature of these relationships with results showing the greatest racial disparities at the upper WC/Weight percentiles where estimated racial differences were as large as 11.6 cm in WC and 16.7 kg in weight. Third, a large, diverse and nationally representative sample of adolescent and adult women was used that increases the generalizability to this subpopulation.

In addition to these strengths, this study has some weaknesses that necessitate mention. First, although the sample used was large, and nationally representative, the conclusions drawn can only be extended to those who were 'healthy enough' to undergo a cardiovascular fitness test. Second, this study was cross-sectional, and as such, causal inferences cannot be drawn from these findings.

Conclusions

In conclusion, the findings from this study demonstrate three important concepts. First, NH Black and Mexican American women exhibited higher levels of central adiposity relative to their NH White counterparts after accounting for fitness. Second, in addition to increased WC, these female minority groups also demonstrated higher weight than NH White women with the estimated magnitude of these differences as much as 16 kg. It is speculated from these findings that the augmented levels of central obesity may be attributable to excess weight. Third, NH Black women showed large differences in WC as compared with NH White only after 15 years of age. Lastly, physical activity (and CRF) and caloric intake have been identified as primary factors in weight status (e.g. gain or loss), and because disparities in WC were present after accounting for fitness, diet may be suggested as an attributable factor to these differences in central adiposity. However, because a majority of the studies examining the role of diet on weight status utilize self-reported measures of caloric intake, no further speculations can be made. Thus, it is strongly recommended that future researchers invest in the development of rigorous, objective measures of dietary intake in order to assess the potential role of caloric intake on the racial/ethnic disparities in central adiposity and weight and other health-related outcomes.

Conflict of interest statement

There are no conflicts of interest to report.

Author contributions

S. M. M., C. S. and A. O. participated in generating the idea for the manuscript. A. O. and M. B. conducted the statistical analysis. M. K. and M. C. provided editorial assistance. All authors were involved in writing/reviewing the paper and had final approval of the submitted version.

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References

1. Heckler MM. *Report of the Secretary's Task Force on Black & Minority Health. Vol I, Executive summary*. HHS: Washington, DC, 1985.
2. Frieden TR. CDC health disparities and inequalities report – United States, 2013. Foreword. Morbidity and mortality weekly report. Surveillance summaries (Washington, DC: 2002). 2013 Nov; 62:1–2.
3. Jackson CL, Szklo M, Yeh HC, et al. Black–white disparities in overweight and obesity trends by educational attainment in the United States, 1997–2008. *J Obes.* 2013; 140743.
4. Freedman DS, Khan LK, Serdula MK, Ogden CL, Dietz WH. Racial and ethnic differences in secular trends for childhood BMI, weight, and height. *Obesity (Silver Spring).* 2006; **14**: 301–308.
5. Cossrow N, Falkner B. Race/ethnic issues in obesity and obesity-related comorbidities. *J Clin Endocrinol Metab.* 2004; **89**: 2590–2594.
6. Beydoun MA, Wang Y. Gender-ethnic disparity in BMI and waist circumference distribution shifts in US adults. *Obesity.* 2006; **17**: 169–176.
7. Cox BD, Whichelow MJ, Prevost AT. The development of cardiovascular disease in relation to anthropometric indices and hypertension in British adults. *Int J Obes Relat Metab Disord.* 1998; **22**: 966–973.
8. Lee S, Bacha F, Gungor N, Arslanian SA. Waist circumference is an independent predictor of insulin resistance in black and white youths. *J Pediatr.* 2006; **148**: 188–194.
9. Trilk JL, Ortaglia A, Blair SN, Bottai M, Church TS, Pate RR. Cardiorespiratory fitness, waist circumference and alanine aminotransferase in youth. *Med Sci Sports Exerc.* 2013; **45**: 722.
10. Fernandez JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African–American, European–American, and Mexican–American children and adolescents. *J Pediatr.* 2004; **145**: 439–444.
11. Bottai M, Frongillo EA, Sui X, et al. Use of quantile regression to investigate the longitudinal association between physical activity and body mass index. *Obesity.* 2014; **22**: E149–E156.
12. McDonald SM, Ortaglia A, Bottai M, Supino C. Differential association of cardiorespiratory fitness and central adiposity among US adolescents and adults: a quantile regression approach. *Prev Med.* 2016; **88**: 1–7.
13. Johnston LD, Delva J, O'Malley PM. Sports participation and physical education in American secondary schools: current levels and racial/ethnic and socioeconomic disparities. *Am J Prev Med.* 2007; **33**: S195–S208.
14. Swift DL, Staiano AE, Johannsen NM, et al. Low cardiorespiratory fitness in African Americans: a health disparity risk factor? *Sports Med* 2013; **43**: 1301–1313.
15. Pivarnik JM, Bray MS, Hergenroeder AC, Hill RB, Wong WW. Ethnicity affects aerobic fitness in US adolescent girls. *Med Sci Sports Exerc* 1995; **27**: 1635–1638.
16. Duncan GE, Sierra M, Zhou XH. Cardiovascular fitness among US adults: NHANES 1999–2000 and 2001–2002. *Med Sci Sports Exerc* 2005; **37**: 1324–1328.
17. Johnson CL, Paulose-Ram R, Ogden CL, et al. National health and nutrition examination survey: analytic guidelines, 1999–2010. National Center for Health Statistics. *Vital Health Stat.* 2013; **2**: 1–24.
18. Centers for Disease Control and Prevention. NHANES cardiovascular fitness procedures manual. Centers for Disease Control and Prevention, National Center for Health Statistics, Revised 2005. 256p. Available from: http://www.cdc.gov/nchs/data/nhanes/nhanes_05_06/CV.pdf. Accessed 10 July 2016.
19. Centers for Disease Control and Prevention. National health and examination survey (NHANES): anthropometric procedures manual. Centers for Disease Control and Prevention, National Center for Health Statistics, Revised 2004. 256p. Available from: http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/Anthropometric_Procedures_Manual.pdf. Accessed 10 July 2016.
20. Lumley T. *Complex Surveys: A Guide to Analysis Using R Vol. 565*. John Wiley & Sons: Hoboken, NY, 2010, pp. 251–253.
21. Camhi SM, Bray GA, Bouchard C, et al. The relationship of waist circumference and BMI to visceral, subcutaneous, and total body fat: sex and race differences. *Obesity (Silver Spring).* 2011; **19**: 402–408.
22. Goran MI, Nagy TR, Treuth MS, et al. Visceral fat in white and African American prepubertal children. *Am J Clin Nutr.* 1997; **65**: 1703–1708.
23. Carroll JF, Chiapa AL, Rodriquez M, et al. Visceral Fat, waist circumference, and BMI: impact of race/ethnicity. *Obesity.* 2008; **16**: 600–607.
24. Seamans MJ, Robinson WR, Thorpe RJ Jr, Cole SR, LaVeist TA. Exploring racial differences in the obesity gender gap. *Ann Epidemiol.* 2015; **25**: 420–425.
25. Rossen LM, Talih M. Social determinants of disparities in weight among US children and adolescents. *Ann Epidemiol.* 2014; **24**: 705–713.e702.
26. Bergouignan A, Trudel G, Simon C, et al. Effect of physical inactivity on the oxidation of saturated and monounsaturated dietary Fatty acids: results of a randomized trial. *PloS Clin Trials.* 2006; **1**:e27.
27. Bergouignan A, Momken I, Lefai E, et al. Activity energy expenditure is a major determinant of dietary fat oxidation and trafficking, but the deleterious effect of detraining is more marked than the beneficial effect of training at current recommendations. *Am J Clin Nutr.* 2013; **98**: 648–658.
28. Archer E. The childhood obesity epidemic as a result of nongenetic evolution: the maternal resources hypothesis. *Mayo Clin Proc.* 2015; **90**: 77–92.
29. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep.* 1985; **100**: 126.
30. Gralla MH, McDonald SM, Breneman C, Beets MW, Moore JB. Associations of objectively measured vigorous physical activity with body composition, cardiorespiratory fitness, and cardiometabolic health in youth: a review. *Am J Lifestyle Med* 2016https://doi.org/10.1177/1559827615624417.

31. Poti JM, Mendez MA, Ng SW, Popkin BM. Highly processed and ready-to-eat packaged food and beverage purchases differ by race/ethnicity among US households. *J Nutr.* 2016; **146**: 1722–1730.
32. Ranjit N, Evans AE, Springer AE, Hoelscher DM, Kelder SH. Racial and ethnic differences in the home food environment explain disparities in dietary practices of middle school children in Texas. *J Nutr Educ Behav.* 2015; **47**: 53–60.
33. Singleton CR, Affuso O, Sen B. Decomposing racial disparities in obesity prevalence: variations in retail food environment. *Am J Prev Med.* 2016; **50**: 365–372.
34. Guerrero AD, Mao C, Fuller B, Bridges M, Franke T, Kuo AA. Racial and ethnic disparities in early childhood obesity: growth trajectories in body mass index. *J Racial Ethn Health Disparities.* 2016; **3**: 129–137.
35. Archer E, Hand GA, Blair SN. Validity of US nutritional surveillance: national health and nutrition examination survey caloric energy intake data, 1971–2010. *PloS One.* 2013; **8**: e76632.
36. Subar AF, Kipnis V, Troiano RP, et al. Using intake biomarkers to evaluate the extent of dietary misreporting in a large sample of adults: the OPEN study. *Am J Epidemiol.* 2003; **158**: 1–13.
37. Chumlea WC, Schubert CM, Roche AF, et al. Age at menarche and racial comparisons in US girls. *Pediatrics.* 2003; **111**: 110–113.
38. Kimm SY, Barton BA, Obarzanek E, et al. Racial divergence in adiposity during adolescence: the NHLBI growth and health study. *Pediatrics.* 2001; **107**:e34.