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Body Mass Index and Waist-to-Height Ratio in Children Ages 6-17:
A Comparison of the United States and India

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ABSTRACT

Body Mass Index and Waist-to-Height Ratio in Children Ages 6-17: A Comparison of the United States and India

By Trishna Narula

BACKGROUND. In recent years, childhood overweight and obesity has become a global epidemic. While childhood obesity is a greater burden in the United States than India, the rate of non-communicable diseases (NCDs) is higher in India. Increasing evidence illustrates that central obesity, or excess abdominal fat, more closely predicts risk of NCDs than obesity in general. While body mass index (BMI), the standard measure of overweight and obesity, does not account for location of body fat, waist-to-height ratio (WHtR) had been found an effective measure of central obesity. The current study aims to determine the prevalence of overweight/obesity through BMI and central obesity through WHtR in children from the US and from India, and to compare levels of WHtR within BMI categories in both populations.

METHODS. A secondary analysis of existing data from the National Health and Nutrition Examination Survey administered by the Centers for Disease Control & Prevention (N=1414) and a survey collected by the All India Institute of Medical Sciences in New Delhi (N=1640) was used to examine pediatric populations ages 6-17 in the US and India, respectively.

RESULTS. The age-adjusted prevalence of overweight/obesity (BMI $\geq$ 25 kg/m^2), was 15.3% (95% confidence interval [CI]: 13.5, 17.2%) in US children and 8.4% (95% CI: 7.1, 9.8%) in Indian children. The age-adjusted prevalence of central obesity (WHtR $\geq$ 0.5) was 27.6% (95% CI: 25.3, 29.9%) in US children and 18.4% (95% CI: 16.5, 20.2%) in Indian children. Mean WHtR in obese children (BMI $\geq$ 30 kg/m^2) was 0.650 ± 0.059 (standard error) in the US and 0.607 ± 0.083 in India. At the 95% confidence level, the prevalence of overweight/obesity ($p < 0.0001$) and central obesity ($p < 0.0001$) were both found significantly higher in children from the US than those from India.

DISCUSSION. Findings indicate central obesity is more prevalent among US than Indian children, both overall and within BMI categories, inconsistent with previous research among adults. Future research should target the 18-and-above population in each country to determine in what age demographic the trend reverses and consider other measures of central obesity such as waist-to-hip ratio.

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BACKGROUND

The Burden of Childhood Overweight, Obesity, and Non-Communicable Disease

In recent years, childhood overweight and obesity has become a global epidemic, with rising trends apparent in both the developed and developing world (Lobstein, Baur, & Uauy, 2004; WHO , 2003). The WHO defines overweight and obesity as "abnormal or excessive fat accumulation that may impair health", where a body mass index (BMI), defined as kilograms divided by square meters height, greater than or equal to 25 kg/m^2 indicates overweight and greater than or equal to 30 kg/m^2 indicates obesity (WHO, 2013).

Worldwide, approximately 43 million children are overweight or obese, an overwhelming 60% increase from 1990 (de Onis, Blossner, & Borghi, 2010). In the United States in particular, the prevalence of obesity in children and adolescents has tripled in the last three decades (Ogden & Carroll, 2010), with about a third of children now either overweight or obese (Ogden, Carroll, Kit, & Flegal, 2012). In India, the prevalence of childhood overweight or obesity is less than half this level at 14%, but due to the large population of the country, this amounts to over 15 million children (Gupta, Goel, Shah, & Misra, 2012).

Research has shown that overweight and obese children often become overweight and obese adults (Rooney, 2011; Serdula, Ivery, Coates, Freedman, Williamson, & Byers, 1993). In addition, studies also demonstrate more immediate consequences of the excess weight, including hypertension, type 2 diabetes, and high cholesterol, that begin during childhood and adolescence (Dietz, 1998; Fagot-Campagna, 2000). Indeed, alongside the epidemic of childhood obesity is the rise of chronic, or non-communicable diseases

(NCDs) around the world. Of nearly 60 million total deaths in 2008 globally, two-thirds were due to chronic diseases such as cardiovascular diseases, diabetes, and cancers (Alwan, Maclean, Riley, et al, 2010).

However, while the burden of childhood obesity weighs much more heavily in the US than in India, the rate of NCDs is drastically higher in low- and middle-income countries such as India – a novel trend not seen until a few decades ago. Today, while NCDs still continue to remain the leading cause of mortality in the developed world, about 80% of the deaths due to chronic diseases actually occur in the developing world. According to the WHO, age-standardized NCD death rates per 100,000 from 2008 in the US were estimated as 458.2 for men and 325.7 for women, while in India they were 781.7 for men and 571.0 for women – over 40% greater (WHO, 2008, 2010a, 2010b).

Definition & Measures of Obesity

As discussed earlier, the WHO defines obesity as a “condition of abnormal or excessive fat accumulation in adipose tissue, to the extent that health may be impaired” (WHO, 1998). The most commonly used measurement of obesity around the world is body mass index (BMI), defined as kilograms/square meters height, and the standard cutoffs are ≥ 25 kg/m^2 for overweight and ≥ 30 kg/m^2 for obese adults (WHO, 1989). [Note that this measurement becomes complicated during youth due to rapid growth and large variability among various ages and both sexes (Flynn et al, 2006), so cutoffs during childhood and adolescence are often recommended instead as the 85th and 95th percentile BMI, for overweight and obese respectively. However, various reference charts of age and sex exist to determine these percentiles, and lacking any clear standard, the adult

BMI cutoffs are sometimes used as a substitute in pediatric research, since they do account for height differences (Ogden & Flegal, 2010).]

Nevertheless, a major limitation of BMI in any population is that it does not differentiate between fat and fat-free weight; in other words, high BMI may not translate to high levels of body fat. Moreover, BMI also cannot illustrate the location or distribution of excess weight around the body. These limitations may be much more significant than previously thought (Freedman et al, 2005; Demerath et al, 2006; Freedman et al 2009).

Central Obesity

Increasing recent evidence shows that fat around the waist and abdomen affect the functioning of key internal organs such as the kidneys, liver, and heart more adversely than fat located elsewhere (Gopinath, Ganesh, Manoj, & Rubiya, 2012). Studies have shown that measures of "central obesity" or "central adiposity" or "abdominal obesity", such as waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR), rather than BMI, more closely predict risk for NCDs (Zimmet, Magliano, Matsuzawa, Alberti, & Shaw, 2005). A recent meta-analysis, including data on over 88,000 subjects from populations in North America, Europe, and Asia, further found that, of these three measures of central obesity, waist-to-height ratio (WHtR) was superior in determining cardiovascular risk (Lee, Huxley, Wildman, & Woodward, 2008). A WHtR greater than or equal to 0.50 is considered indicative of central obesity, among children, adolescents, and adults alike (Schwandt et al, 2010; Hsieh et al, 2010; Freedman et al, 2007), and thus allows for promotion of the convenient public health message for individuals of both sexes and all ages: "keep your waist circumference to less than half of your height" (McCarthy & Ashwell, 2006).

Among youth, one large study using data from the National Health and Nutrition Examination Survey (NHANES) on over 7,600 subjects aged 4-17 in the US compared WHtR and age- and sex-specific BMI percentiles, and found that WHtR was more closely associated with adverse cardiovascular risk (Kahn, Imperatore, & Cheng, 2005). Another study found that even among children with overweight or obese BMI levels, those with high WHtR had elevated metabolic risk factor levels while those with low WHtR had risk levels very close to those of children with normal BMI (Khoury, Manlhiot, & McCrindle, 2013). Indeed, further research specifically among children and adolescents in the past decade has continuously demonstrated that WHtR is effective in detecting increased risk for both cardiovascular and metabolic diseases (Mokha et al, 2010; Freedman et al, 2007; Maffeis et al, 2008; Hara et al, 2002; Srinivasan et al, 2009). Yet while many guidelines from medical associations in different countries exist regarding the potential benefits of measures of central obesity such as WHtR, there are currently no standardized screening recommendations for use among children and adolescents (Barlow, 2007; Lau, Douketis, Morrison, Hramiak, & Sharma, 2007; Baumer, 2007).

Asian adult populations, who tend to have lower levels of BMI yet higher levels of NCDs compared to Caucasian adult populations, have higher rates of central adiposity per given body weight (WHO Expert Consultation, 2004; Ramachandran, Chamukuttan, Shetty, Arun, & Susairaj, 2012). Several studies in South Asia in particular, which includes India, demonstrate a rather high prevalence of abdominal obesity among adults

(Misra & Vikram, 2004; Misra et al, 2001; Dhawan et al, 1994; Hughes et al, 1997; Lean et al, 2001), with one study based in South India reporting 31.4% abdominal obesity (Ramachandran et al, 2003). Another adult study from New Delhi, India, found that about 66% of men and 88% of women with a non-obese BMI level still had one or more cardiovascular risk factors (Vikram et al, 2003). Indeed, "non-obese" South Asian adults are often still "centrally obese" (Misra & Khuraan, 2008; Ruderman et al, 1998). While the WHO has concluded that Asian adults have a higher risk of type 2 diabetes and cardiovascular diseases at "normal" BMI levels, a lack of sufficient data has been cited to change any standards in screening (WHO Expert Consultation, 2004).

Thus, the literature illustrates that WHtR is a stronger predictor of risk for NCDs than BMI, and that the relationship between WHtR and BMI may differ among populations in various parts of the world. Research shows that adults in India have lower obesity levels yet higher central obesity levels than adults in the US; however, till date, this phenomenon has not been studied in children in these two countries. Could we be missing a pediatric population at an exceptionally high risk for non-communicable diseases?

METHODS

Research Questions

The current study aims to:

1. Determine the age-adjusted levels of body mass index (BMI) and waist-to-height ratio (WHtR) among non-Hispanic white children from the United States and Asian Indian children from India aged 6-17 years old.

2. Compare the prevalence of central obesity using waist-to-height ratio (WHtR) within each body mass index (BMI) group in the US versus India pediatric populations.

Study Design

The current study was a secondary analysis that examined data from the National Health and Nutrition Examination Survey, representing the United States children, and from a cross sectional survey conducted by a medical institution in New Delhi, representing children from India.

Since this study does not constitute Human Subject Research according to federal regulations, the Institutional Review Board (IRB) of Emory University determined it did not require IRB review [Appendix A].

Description of US Data

The National Health and Nutrition Examination Surveys (NHANES) is a study administered by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC). NHANES uses interviews and physical examinations among a sample of about 5,000 adults and children annually to assess the health and nutritional status of the United States. The sample is designed to be representative of the national population, with participants selected by multi-stage area probability sampling and fifteen different counties across the US sampled each year.

For purposes of the current study, the two latest available NHANES datasets were used: 2007-2008 and 2009-2010, representing two 2-year cycles. These surveys were approved by the NCHS Institutional Review Board and Research Ethics Board. Written consent from parents was obtained from all participants below 18 years of age. Additionally, written assent was obtained for children 7 to 11 years old, and informed consent from those 12 and above. All available NHANES data are completely anonymous and de-identified (CDC, 2013).

The 2007-2008 and 2009-2010 NHANES survey results included data on a total of 10,149 and 10,537 participants, respectively. For the present analyses, these datasets were restricted to non-Hispanic white children aged 6-17, resulting in a sample size of 668 and 746, respectively, and 1414 total.

The main NHANES variables included in the present study were ID number, age, gender, height, weight, BMI, and waist circumference. Age and gender were self-reported. Height was measured with a stadiometer against a flat vertical surface, and weight was measured using a digital weight scale with the participant wearing an examination gown. Height and weight measurements were then used to calculated body mass index, or BMI (kilograms weight divided by square meters height). Waist circumference was measured to the nearest 0.1 cm using a steel measuring tape around the top of the iliac crest (CDC, 2013).

Description of India Data

The data from India were obtained from a medical institution that had conducted a cross sectional health survey of 3700 children aged 5-18 and enrolled in private schools in New Delhi. The study was approved by the institutional ethics committee of the Institute of Nuclear Medicine and Allied Sciences (INMAS) in New Delhi. All child participants enrolled had given their own verbal consent, in addition to consent by their individual schools and their parents or guardians. All available data are completely anonymous and de-identified.

Since there were fewer than twenty 5-year-olds and 18-year-olds each in the sample, these age groups were previously removed from the dataset. Restricting the data to the current study purposes, the final sample used presently included 1640 children aged 6-17.

The variables included were ID number, age, gender, height, weight, BMI, and waist circumference. Age and gender were self-reported. Height was recorded to the nearest 0.001 m and weight to the nearest 0.1 kg, with subjects wearing indoor clothing and without any footwear. Height and weight measurements were then used to calculated body mass index, or BMI (kilograms weight divided by square meters height). Waist circumference was measured between the iliac crest and lowest margin of the ribs.

Data Analysis

All statistical analyses were conducted using SAS software, version 9.3 (Cary, NC).

The two datasets, US-NHANES and India-Delhi, were merged, yielding a total of 3054 observations and seven variables: ID number, age (years), gender (male/female), height (cm), weight (kg), BMI (kg/m^2), and waist circumference (cm).

Simple numerical summaries of the data were examined in order to identify data errors, outliers, and implausible and missing values. None of the above were found.

New variables were created to represent country of data origin (US/India), waist-to-height ratio [WHtR] (waist circumference divided by height), WHtR category (normal: < 0.5 and elevated: ≥ 0.5), and two types of body mass index [BMI] categorization according to standard cutoffs (categorized BMI variable 1: normal: < 25 kg/m2, overweight: ≥ 25 kg/m^2 and < 30 kg/m^2, and obese: ≥ 30 kg/m^2; categorized BMI variable 2: normal: < 25 kg/m2, and overweight/obese: ≥ 25 kg/m^2).

Basic descriptive statistics, including gender frequencies and means and standard deviations of age, BMI, weight, height, waist circumference, and WHtR within each country, were examined.

Age-adjusted prevalence estimates of BMI (normal versus overweight/obese) and WHtR (normal versus elevated) within each country were calculated with 95% confidence intervals, with standard cutoffs of BMI and WHtR as described above. Direct age-standardization was used in order to appropriately compare estimates between the two countries; both country samples were standardized to US population proportions based on 2000 US Census data (United States Census Bureau, 2013), as recommended for NHANES data by the National Center for Health Statistics (NCHS) (CDC, 2013). Thus, standard age proportions were calculated by dividing the age-specific population by the total population. Proportions and prevalence estimates were calculated for the entire sample age group (6-17 years), as well as for two age subgroups with equal, five-year ranges (6-11 years and 12-17 years), in order to investigate differences between younger and older children.

For each country, mean WHtR within each of the three BMI groups (normal, overweight, and obese), was calculated and plotted on a graph, with error bars displaying standard error above and below each mean. The same was repeated for both male and female children separately in each country to investigate any gender differences within countries.

In each country, the number of subjects within each BMI category (normal, overweight, and obese), as well as the mean BMI within each BMI category, were examined. The number and percentage of subjects with elevated WHtR levels, as defined above, within these BMI categories, was also examined for each country.

Pearson's chi-square tests of homogeneity with one degree of freedom were performed to evaluate whether the levels of overweight/obesity (as defined by BMI cutoffs) and levels of central obesity (as defined by WHtR cutoffs) are significantly different in children in the US versus in India. Nine of these tests were performed, with the null hypotheses defined as follows: (1) the prevalence of overweight/obesity (BMI $\geq$ 25 kg/m^2) is the same in US and Indian children; (2) the prevalence of central obesity (WHtR $\geq$ 0.5) is the same in US and Indian children; (3) the prevalence of central obesity (WHtR $\geq$ 0.5) is the same in US and Indian children who are overweight/obese (BMI $\geq$

25 kg/m^2); (4) the prevalence of central obesity (WHtR ≥ 0.5) is the same in US and Indian children who are overweight (25 kg/m^2 $\leq$ BMI < 30 kg/m^2); and (5) the prevalence of central obesity (WHtR ≥ 0.5) is the same in US and Indian children who are obese (BMI $\geq$ 30 kg/m^2). Tests (1) and (2) were repeated for age groups 6-11 and 12-17 years.

For each of the nine tests, the appropriate assumptions were met to use the chi-square test of homogeneity, including presence of two independent random samples (US and India) and a sufficiently large sample size in each category, and a p-value of < 0.05 was used for statistical significance to reject the null hypothesis.

RESULTS

Descriptive Statistics

A total of 3052 children were analyzed, including 1414 from the US sample and 1640 from the India sample.

The mean age of the US children was 11.6 years (standard deviation [SD] = 3.5), with N=1059 (49.1%) females and N=1099 (50.9%) males. The mean age of children from the India sample was 13.1 years (SD = 2.6), with N=815 (49.7%) females and N=825 (50.3%) males.

The mean body mass index (BMI) for children in the US was 20.5 kg/m^2 (SD = 5.2), and that in India was 19.4 kg/m^2 (SD = 4.0). The mean weight for children in the US was 48.8 kg (SD = 21.2), and that in India was 46.8 kg (SD = 14.0). The mean height for children in the US was 150.6 cm (SD = 19.2), and that in India was 154.0 cm (SD = 13.2). The mean waist circumference for children in the US was 72.6 cm (SD = 14.9), and that in India was 68.9 cm (SD = 11.8). The mean waist-to-height ratio (WHtR) for children in the US was 0.481 (SD = 0.071), and that in India was 0.447 (SD = 0.062).

Age-Adjusted Prevalence of Overweight/Obesity & Central Obesity in US & India

In the full sample of children aged 6-17 years, the age-adjusted prevalence of overweight/obesity, defined as BMI ≥ 25 kg/m^2, was 15.3% (95% confidence interval [CI]: 13.5, 17.2%) in US children and 8.4% (95% CI: 7.1, 9.8%) in Indian children [Table 1]. The age-adjusted prevalence of central obesity in the same sample, defined as WHtR ≥ 0.5, was 27.6% (95% CI: 25.3, 29.9%) in US children and 18.4% (95% CI: 16.5, 20.2%) in Indian children [Table 1].

In a subgroup of younger children aged 6-11 years, the age-adjusted prevalence of overweight/obesity, defined as BMI ≥ 25 kg/m^2, was 6.7% (95% confidence interval [CI]: 4.9, 8.4%) in US children and 3.6% (95% CI: 1.8, 5.4%) in Indian children [Table 2]. The age-adjusted prevalence of central obesity in the same sample, defined as WHtR ≥ 0.5, was 26.0% (95% CI: 22.9, 29.0%) in US children and 16.7% (95% CI: 13.1, 20.3%) in Indian children [Table 2].

In a subgroup of older children aged 12-17 years, the age-adjusted prevalence of overweight/obesity, defined as BMI ≥ 25 kg/m^2, was 25.9% (95% confidence interval [CI]: 22.5, 29.3%) in US children and 10.0% (95% CI: 8.4, 11.7%) in Indian children [Table 2]. The age-adjusted prevalence of central obesity in the same sample, defined as WHtR ≥ 0.5, was 29.5% (95% CI: 26.0, 33.1%) in US children and 18.9% (95% CI: 16.75, 21.1%) in Indian children [Table 2].

Levels of Central Obesity within BMI Categories

In the US sample of children aged 6-17 years, mean waist-to-height ratio (WHtR) was 0.459 ± 0.048 (standard error) in the normal BMI group (BMI < 25 kg/m^2), 0.565 ± 0.049 in the overweight group (25 kg/m^2 ≤ BMI < 30 kg/m^2), and 0.650 ± 0.059 in the obese group (BMI ≥ 30 kg/m^2), where WHtR ≥ 0.5 indicates central obesity [Figure 1]. In the Indian sample of children aged 6-17 years, mean WHtR was 0.437 ± 0.053 in the normal BMI group (BMI < 25 kg/m^2), 0.532 ± 0.058 in the overweight group (25 kg/m^2 ≤ BMI < 30 kg/m^2), and 0.607 ± 0.083 in the obese group (BMI ≥ 30 kg/m^2), where WHtR ≥ 0.5 indicates central obesity [Figure 1].

Among US male children aged 6-17, mean WHtR was 0.455 ± 0.049 in the normal BMI group, 0.558 ± 0.050 in the overweight group, and 0.640 ± 0.057 in the obese group [Figure 2a]. Among US females, mean WHtR was 0.464 ± 0.046 in the normal BMI group, 0.660 ± 0.060 in the overweight group, and 0.573 ± 0.047 in the obese group [Figure 2a].

Among Indian male children aged 6-17, mean WHtR was 0.450 ± 0.052 in the normal BMI group, 0.539 ± 0.058 in the overweight group, and 0.620 ± 0.051 in the obese group [Figure 2b]. Among Indian females, mean WHtR was 0.426 ± 0.051 in the normal BMI group, 0.524 ± 0.057 in the overweight group, and 0.589 ± 0.114 in the obese group [Figure 2b].

In the US sample (N=1414), 1197 subjects were classified into the normal BMI category (BMI < 25 kg/m^2), with a mean BMI of 18.6 kg/m^2 (standard deviation [SD]: 3.1 kg/m^2) within the category; 140 subjects were classified into the overweight category (25 kg/m^2 ≤ BMI < 30 kg/m^2), with a mean BMI of 27.0 kg/m^2 (SD: 1.5 kg/m^2); and 77 subjects were classified as obese (BMI ≥ 30 kg/m^2), with a mean BMI of 34.1 kg/m^2 (SD: 3.5 kg/m^2). Of the normal BMI group in the US, 190 subjects (15.9% of the US normal BMI group) were classified as centrally obese (WHtR ≥ 0.5); of the overweight group, 125 (89.3%) were classified as centrally obese; and of the obese group, 75 (97.4%) were centrally obese [Table 3].

In the India sample (N=1640), 1502 subjects were classified into the normal BMI category (BMI < 25 kg/m^2), with a mean BMI of 18.6 kg/m^2 (standard deviation [SD]: 2.9 kg/m^2) within the category; 112 subjects were classified into the overweight category (25 kg/m^2 ≤ BMI < 30 kg/m^2), with a mean BMI of 26.8 kg/m^2 (SD: 1.3 kg/m^2); and 26 subjects were classified as obese (BMI $\geq$ 30 kg/m^2), with a mean BMI of 32.7 kg/m^2 (SD: 2.7 kg/m^2). Of the normal BMI group in India, 198 subjects (13.2% of India's normal BMI group) were classified as centrally obese (WHtR $\geq$ 0.5); of the overweight group, 82 (73.2%) were classified as centrally obese; and of the obese group, 21 (80.8%) were centrally obese [Table 3].

Chi-Square Test Results

At the 95% confidence level, the prevalence of overweight/obesity (BMI $\geq$ 25 kg/m^2) was found to be significantly higher in children from the US than in children from India ($p < 0.0001$), and the prevalence of central obesity (WHtR $\geq$ 0.5) was also found significantly higher in US children ($p < 0.0001$).

In children aged 6-11 years old too, both the prevalence of overweight/obesity ($p = 0.0286$) and the prevalence of central obesity ($p = 0.0003$) were found to be significantly higher in US than Indian children. Similarly, in ages 12-17 years, significantly more US children were found to be overweight/obese ($p < 0.0001$) as well as centrally obese ($p < 0.0001$).

Furthermore, the prevalence of central obesity (WHtR $\geq$ 0.5) was found to be significantly higher in US versus Indian children among children who are overweight or obese (BMI $\geq$ 25 kg/m^2; $p < 0.0001$), children who are overweight (25 kg/m^2 $\leq$ BMI < 30 kg/m^2; $p = 0.0009$), and among children who are obese (BMI $\geq$ 30 kg/m^2; $p = 0.0036$).

DISCUSSION

The current study determined the prevalence of overweight/obesity through BMI and central obesity through WHtR among non-Hispanic white children from the United States and Asian Indian children from India aged 6-17 years old, and compared levels of WHtR within BMI categories in both populations.

As discussed earlier, the literature suggests that the presence of central obesity, as measured by a waist-specific measure such as WHtR, affect internal organs more adversely, and more closely predicts elevated risk for non-communicable diseases (NCDs) such as diabetes and cardiovascular disease, than the more general measure BMI (Gopinath, Ganesh, Manoj, & Rubiya, 2012; Zimmet, Magliano, Matsuzawa, Alberti, & Shaw, 2005). In addition, previous research has found that South Asian adults, who have lower levels of BMI yet higher levels of NCDs as compared to the US adult population, have higher rates of central obesity (WHO Expert Consultation, 2004; Ramachandran, Chamukuttan, Shetty, Arun, & Susairaj, 2012; Misra & Vikram, 2004; Misra et al, 2001; Dhawan et al, 1994; Hughes et al, 1997; Lean et al, 2001).

Summary of Findings: Prevalence of Overweight/Obesity & Central Obesity

Current findings definitely reflect the worldwide concern of childhood obesity reaching epidemic levels across developing and developed countries alike (Lobstein, Baur, & Uauy, 2004; WHO , 2003), with results depicting over 15% overweight/obesity and nearly 28% central obesity in US children, and over 8% overweight/obesity and over 18% central obesity in Indian children.

However, these findings suggest that the trend found in adults (i.e., Indian adults, who have lower levels of BMI and higher levels of NCDs compared to US adults, also have higher rates of central obesity) may not be true for children. Results illustrate that not only are levels of overweight and obesity (according to BMI) higher in children in the United States versus children in India, as expected, but also that levels of central obesity, as determined by an elevated WHtR, are higher in the US children as well. The same results were found when isolating the younger (6-11 years) and older children (12-17 years).

Summary of Findings: Levels of Central Obesity within BMI Categories

Furthermore, when examining children within BMI categories, prevalence of central obesity was significantly higher in US than Indian children in both the overweight ($p = 0.0009$) and obese ($p = 0.0036$) BMI children.

It is interesting to note, however, that within obese children only, 97.4% in the US were categorized as also centrally obese, while only 80.8% of those in India had an elevated WHtR, suggesting obesity and central obesity may be more positively correlated in the US than in India.

Discussion of Findings

Nevertheless, while many of these findings were unexpected, they represent an important step forward in increasing our understanding of obesity, central obesity, and age demographics in both developing and developed countries, generating novel questions to investigate, and developing effective prevention strategies. If adults but not children in India have higher levels of central obesity as compared to the US population, perhaps unique changes contributing to this increase in abdominal fat are occurring in Indians later in life, or perhaps risk factors for central obesity were greater in decades past than in the present. It may also be that children in India tend to have excess fat in a different area of their body than the waist, such as the hip area, which may also be an important risk factor for NCDs.

Limitations

While the current study had a large sample size of children both from the US and from India, the subjects in India were all drawn from private, fee-paying schools, and thus may represent a higher socioeconomic background than the rest of the country. A previous study conducted in eleven cities across India (N=6198) found that overweight and obesity according to BMI cutoffs was more prevalent in higher socioeconomic strata, central obesity according to waist circumference was similar across socioeconomic strata, and central obesity according to waist-to-hip ratio was more prevalent in lower socioeconomic strata (Gupta, Deedwania, Sharma, Gupta, Guptha, et al, 2012). Thus, the effects of this sampling bias on our study results are unknown.

In addition, waist circumference (WC) was measured slightly differently in the US and India physical examinations, with US NHANES tape measurements around the top of the iliac crest and New Delhi tape measurements between the iliac crest and lowest margin of the ribs. In a recent study comparing three different anatomic sites for measurement of WC (WC_{rib}, around the lowest rib; $WC_{iliac\ crest}$, around the top of the iliac crest; and WC_{middle}, in between the two), researchers found WC_{middle} (used in the New Delhi study) gave smaller measurement values than $WC_{iliac\ crest}$ (used in NHANES)

(Bosy-Westphal et al, 2010). Thus, in the current analyses, estimates of waist-to-height ratio (WC divided by height) and thus prevalence of central obesity among Indian children may have been underestimated.

Lastly, the current analyses used standard BMI cutoffs rather than the 85^{th} and 95^{th} percentile often recommended for children. However, various reference charts of children according to age and sex exist in different populations, lacking any clear international standard to determine the 85^{th} and 95^{th} percentiles (Ogden & Flegal, 2010). Thus while using the standard BMI cutoffs may have caused some error in classifying children into normal, overweight, and obese groups within each country, they are preferred for comparisons between countries.

FUTURE DIRECTIONS

The current study is the first of its kind to compare body mass index (BMI) and waist-to-height ratio (WHtR), a measure of central obesity, among children in the US and in India. Given previous research illustrating that Indian adults are more centrally obese than US adults and current findings depicting that US children are more centrally obese than Indian children, future research should look at young adults 18 and above in the US and India in attempt to find in what age group the trend reverses, and what contributes to this change. In addition, research using different measures of central obesity, such as waist-to-hip ratio, and comparing children from both countries, could help determine other ways in which body fat distribution varies among the two different populations, and how these differences may or may not be partially contributing to differences in levels of non-communicable diseases (NCDs). It would also be beneficial to consider children of Asian Indian descent born and brought up in the US, to help distinguish between genetic and environmental factors in the differences between overweight, obesity, and central obesity found in the current study. Attention should be given in all future studies to ensure that samples are representative of the target population and that clinical measurements across populations are carried out via the same procedures, to the greatest extent possible. Finally, researchers should continue to investigate the reasons behind the high levels of, and develop prevention programs targeted towards reducing, overweight, obesity, and central obesity in children around the world.

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TABLES

TABLE 1. Age-adjusted prevalence, with 95% confidence intervals, of overweight/obesity using body mass index (BMI) and central obesity using waist-to-height ratio (WHtR) among children aged 6-17 years in US and India.

	BMI* (95% CI)		**WHtR** (95% CI)**	
	Normal	Overweight/ Obese	Normal	Elevated
US	84.7% (82.8, 86.6%)	15.3% (13.5, 17.2%)	72.4% (71.1, 73.7%)	27.6% (25.3, 29.9%)
India	91.6% (89.3, 93.9%)	8.4% (7.1, 9.8%)	81.6% (79.7, 83.5%)	18.4% (16.5, 20.2%)

* BMI groups defined as: Normal (< 25 kg/m^2); Overweight/Obese (≥ 25 kg/m^2)
** Waist-to-height ratio (WHtR) groups defined as: Normal (< 0.5); Elevated (≥ 0.5)

TABLE 2. Age-adjusted prevalence, with 95% confidence intervals, of overweight/obesity using body mass index (BMI) and central obesity using waist-to-height ratio (WHtR) among children aged 6-11 years and 12-17 years in US and India.

	Ages 6-11				**Ages 12-17**			
	BMI* (95% CI)		**WHtR** (95% CI)**		**BMI* (95% CI)**		**WHtR** (95% CI)**	
	Normal	Overweight/ Obese	Normal	Elevated	Normal	Overweight/ Obese	Normal	Elevated
US	93.3% (91.5, 95.0%)	6.7% (4.9, 8.4%)	74.0% (70.9, 77.1%)	26.0% (22.9, 29.0%)	74.1% (70.7, 77.5%)	25.9% (22.5, 29.3%)	70.5% (67.0, 74.0%)	29.5% (26.0, 33.1%)
India	96.4% (95.0, 98.2%)	3.6% (1.8, 5.4%)	83.3% (81.6, 85.0%)	16.7% (13.1, 20.3%)	90.0% (86.4, 89.8%)	10.0% (8.4, 11.7%)	81.1% (78.9, 83.3%)	18.9% (16.7, 21.1%)

* BMI groups defined as: Normal (< 25 kg/m^2); Overweight/Obese (≥ 25 kg/m^2)
** Waist-to-height ratio (WHtR) groups defined as: Normal (< 0.5); Elevated (≥ 0.5)

TABLE 3. Prevalence of central obesity using waist-to-height ratio (WHtR) cut-offs in each body mass index (BMI) group, among children in US and India.

Country	BMI group*	*N*	Number with central obesity (%)**
US	Normal	1197	190 (15.9%)
	Overweight	140	125 (89.3%)
	Obese	77	75 (97.4%)
India	Normal	1502	198 (13.2%)
	Overweight	112	82 (73.2%)
	Obese	26	21 (80.8%)

* BMI groups defined as: Normal (< 25 kg/m^2); Overweight (≥ 25 kg/m^2 and < 30 kg/m^2); Obese (≥ 30 kg/m^2)
** Central obesity defined by waist-to-height ratio (WHtR) ≥ 0.5

FIGURES

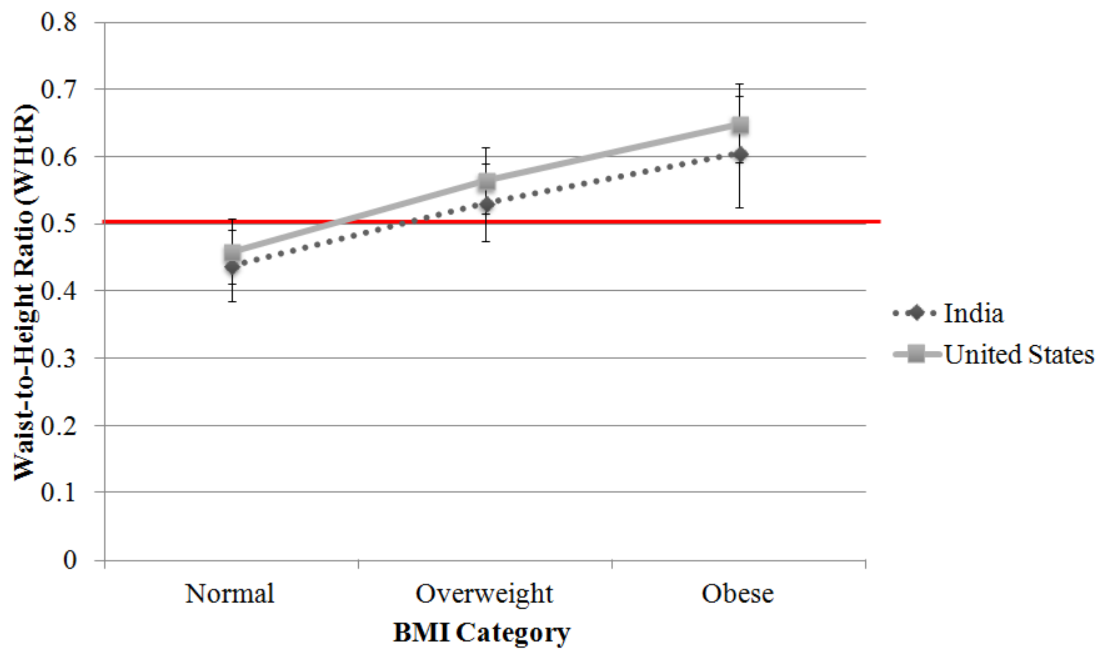

FIGURE 1. Among children aged 6-17 years in US and India, mean waist-to-height ratio (WHtR) across standard body mass index (BMI) groups, defined as Normal (< 25 kg/m^2), Overweight (≥ 25 kg/m^2 and < 30 kg/m^2), and Obese (≥ 30 kg/m^2). WHtR < 0.5 is considered normal and ≥ 0.5 is considered elevated and a sign of central obesity. Error bars display standard error above and below mean.

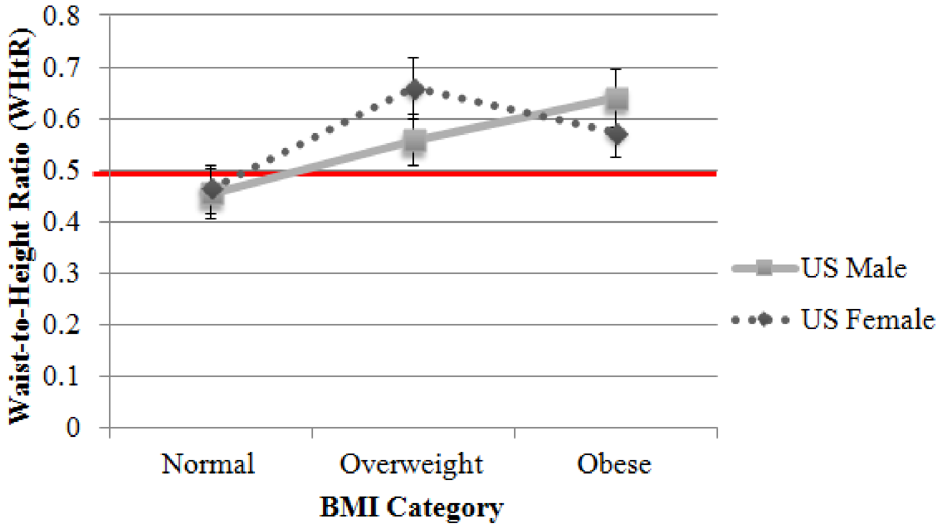

FIGURE 2a. Among male and female children aged 6-17 years in the US, mean waist-to-height ratio (WHtR) across standard body mass index (BMI) groups, defined as Normal (< 25 kg/m^2), Overweight (≥ 25 kg/m^2 and < 30 kg/m^2), and Obese (≥ 30 kg/m^2). WHtR < 0.5 is considered normal and ≥ 0.5 is considered elevated and a sign of central obesity. Error bars display standard error above and below mean.

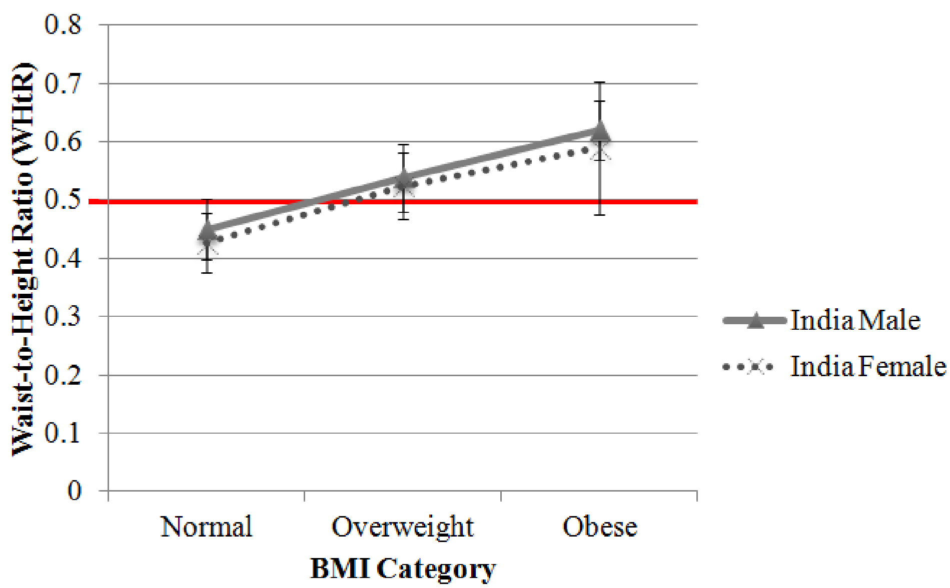

FIGURE 2b. Among male and female children aged 6-17 years in India, mean waist-to-height ratio (WHtR) across standard body mass index (BMI) groups, defined as Normal (< 25 kg/m^2), Overweight (≥ 25 kg/m^2 and < 30 kg/m^2), and Obese (≥ 30 kg/m^2). WHtR < 0.5 is considered normal and ≥ 0.5 is considered elevated and a sign of central obesity. Error bars display standard error above and below mean.

APPENDICES

Appendix A: IRB Non-Human Subjects Determination Letter

EMORY UNIVERSITY

Institutional Review Board

4/23/2013

RE: **Determination: No IRB Review Required**
eIRB#: IRB00062732
Title: ***Comparison of Waist Circumference and Waist-to-Height Ratio within BMI Strata in Schoolchildren in India and the US***
PI: Neil Mehta, PhD

Dear Dr. Mehta and Ms. Narula,

Thank you for requesting a determination from our office about the above-referenced project. Based on our review of the materials you provided, we have determined that it does not require IRB review because it does not meet the definition of "research" or "clinical investigation" involving "human subjects" as set forth in Emory policies and procedures and federal rules, if applicable. Specifically, in this project, you have analyzed completely de-identified data. While all of it was not publicly available, the data that was not was obtained with the expressed permission of the PI who collected it in India. Documents saying as much can be found in the withdrawn eIRB submission referenced above.

Please note that this determination does not mean that you cannot publish the results. If you have questions about this issue, please contact me.

This determination could be affected by substantive changes in the study design, subject populations, or identifiability of data. If the project changes in any substantive way, please contact our office for clarification.

Thank you for consulting the IRB.

Sincerely,

Michael Arenson, MA
Analyst Assistant

CC: Trishna Harneet Narula

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