Original Article

Prevalence of Obesity in India and Its Neurological Implications: A Multifactor Analysis of a Nationwide Cross-Sectional Study

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Abstract

Background: India is undergoing a rapid epidemiological transition, from underweight to overweight/obese population. Obesity is a major risk factor in type 2 diabetes and cardiovascular diseases, and is also implicated as a factor in neurological diseases such as Alzheimer's disease. A robust, pan-Indian estimate of obesity is not yet available.

Purpose: This study estimates the pan-Indian prevalence of obesity, stratified across nonmodifiable (age and gender) and modifiable (education and physical activity levels) factors, and across zones and urban/rural.

Methodology: Data for 1,00,531 adults from a nationwide randomized cluster sample survey (*Niyantrita Madhumeha Bharata* 2017, phase 1) were analyzed. Obesity was determined using body mass index, and cross-tabulations were calculated across zones, age, gender, education, physical activity, and area. To determine statistical significance, *t*-tests were used. The odds of obesity within each category of the various factors were calculated using binary logistic regression.

Results: Prevalence of obesity in India is 40.3%. Zonal variations were seen as follows: south highest at 46.51% and east lowest at 32.96%. Obesity was higher among women than men (41.88% vs. 38.67%), urban than rural (44.17% vs. 36.08%), and over 40 than under 40 (45.81% vs. 34.58%). More education implied a higher obesity (44.6% college vs. 38% uneducated), as did lowered physical activity (43.71% inactive vs. 32.56% vigorously active). The odds ratio for physical activity was 3.83, stronger than age (1.58), education (1.4), urban (1.3), and gender (1.2).

Conclusion: Obesity levels in India are very high, across all zones. The odds of being obese increases with age, and is higher among women and among urban dwellers. Obesity is the highest among aging urban men and women who are college educated and are sedentary. Physical activity and aging are the strongest determinants of obesity. Given the high cost of obesity in terms of type 2 diabetes, cardiovascular diseases, and Alzheimer's disease, urgent public health measures are necessary to reduce its impact.

Keywords

Obesity, alzheimer, NMB, diabetes, obesity prevalence

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Introduction

Obesity is a condition characterized with an increase in the size and amount of fat cells in the body. It is a chronic disorder that is officially classified as a disease by the World Health Organization (WHO), and also by several other national and international organizations.[1] Although an easily recognizable condition by specialists and laypersons alike, there does not yet exist a widely accepted clinical definition of obesity. The definition of the term by the Obesity Medicine Association captures both its complex etiology and diverse consequences: "a chronic, relapsing, multi-factorial, neurobehavioral disease, wherein an increase in body fat promotes adipose tissue dysfunction and abnormal fat mass physical forces, resulting in adverse metabolic, biomechanical and psychosocial health consequences."[2] According to the WHO, obesity is a major risk factor for noncommunicable diseases such as heart disease, stroke, type 2 diabetes, certain cancers (endometrial, breast, ovarian, prostate, liver, gallbladder, kidney, and colon), and osteoarthritis.[3] Obesity is also

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associated with unemployment, social disadvantages, and reduced socioeconomic productivity.[4]

The worldwide prevalence of obesity is reaching pandemic proportions. The WHO had estimated that in 2016, more than 1.9 billion adults worldwide (39%) were overweight, and over 650 million (13%) were obese.[3] Furthermore, researchers from the NCD Risk Factor Collaboration reported that the obesity prevalence increased in every country between 1975 and 2016; the greatest increases were noted in South Asia, Southeast Asia, the Caribbean, and Southern Latin America.[5] The current trajectory of prevalence acceleration would result in almost half of the world's population being overweight or obese by 2030.[6]

Obesity is commonly studied as a risk factor for type 2 diabetes and/or cardiovascular morbidities. However, both the causes for, and the effect of, obesity have a neurological component as well. For example, recent studies have suggested that an impaired appetite regulation in obese individuals is because of cerebral insulin resistance, leading to both an increased hepatic glucose production and a reduced muscle glucose intake, thus implicating the brain directly in the pathogenesis of the metabolic syndrome, and making it one of the members of the so-called ominous octet.[7] The effects of obesity on the brain are an area of intense investigative activity. New evidence is emerging which indicates that obesity without type 2 diabetes results in a three-fold increase in the risk of developing Alzheimer's disease (AD).[8] Furthermore, because of the strong correlation between AD and impairments in insulin and insulin-like growth factor gene expression and signaling in the brain, AD may represent a brain-specific form of diabetes, sometimes referred to as "type 3 diabetes."[9]

Not surprisingly, obesity is associated with huge personal, social, and economic costs. It is estimated that obesity is responsible for 5% of all global deaths. The worldwide economic impact of obesity is estimated to be US$2 trillion, putting it in the same category as smoking and armed conflict. There is also growing evidence that socioeconomic productivity is undermined by obesity.[10] It is to be noted that these estimates do not include the neurological aspect of obesity, so the true cost is likely to be higher.

As noted before, the South Asian region—which includes India—has one of the fastest growing obesity rates in the world. It is estimated that there are 135 million obese individuals in India.[11] The Indian National Family Health Survey-4 reported that in the 10-year period from 2005 and 2006 to 2015 and 2016, obesity among women between the ages of 15 and 49 years increased from 13% to 21%; during the same time period, obesity among men between the ages of 15 and 49 years increased from 9.3% to 19%.[12]

It is, therefore, clear that India is experiencing a very rapid epidemiological transition. Undernutrition and the accompanying outcome of an underweight population are now being replaced by an overweight and obese population. Because obesity is a major risk factor for most noncommunicable diseases, a critical component of public health policy is the prevention and management of this epidemic. However, as noted by the WHO, obesity is one of the most neglected public health problems.[13] While there are several studies reporting localized obesity prevalence in specific states, zones, communities, cities, and locales, there is no collective data across the country as a whole. The best prevalence estimate available comes from a pooled analysis of 14 individual studies.[14]

There is an urgent need to quantify the scale of the problem—that is, to get a robust estimate of the prevalence of obesity in India—so that a proper public policy can be shaped to handle the problem. The present study analyzes data from a large pan-India study conducted in 2017, the *Niyantrita Madhumeha Bharata Abhiyaan* (Diabetes Free India), or NMB-2017[15,16] to determine obesity prevalence.

Methodology

Study Design

Niyantrita Madhumeha Bharata (Control of Diabetes in India) 2017, or NMB-2017, was a two-phased study undertaken across 29 most populous states/union territories in India. The twin objectives of the study were as follows.

1. Phase 1—a rapid survey to estimate the prevalence of obesity, diabetes, prediabetes, and high-risk population simultaneously in all zones of India in 2017.
2. Phase 2—to conduct an randomized controlled trial (RCT) using a validated yoga lifestyle protocol.

Because this study is focused on data from phase 1 of NMB-2017, the details of phase 2, which have been reported elsewhere,[16] will not be elaborated further.

Phase 1[15] was a nationwide randomized cross-sectional survey using a multilevel stratified cluster sampling technique with random selection among urban and rural populations covering 65 districts of the most populous states (25) and union territories (4) of the country. In a door-to-door survey, researchers used a short questionnaire to collect data on diabetes status and diabetes risk.

Sampling was done at four levels: (a) zones, (b) states, (c) districts, and (d) villages (rural) or towns (urban), with a randomized cluster sampling of census enumeration blocks (CEBs) in each town. The states and union territories were grouped into seven geographical regions based on their sociocultural similarities with a small deviation from the grouping available in the national directory.[17] Table 1 shows the composition of each zone.

The districts in the state were the first level of sampling. In accordance with the sampling plan, it was decided to select 10% of the total number of districts in the country, and correspondingly 10% of the districts in each state. For states with ≤10 districts, one district was chosen, and for states with 10 to 30 districts, two districts were chosen. To ensure that

Table 1. States and Union Territories in Each Zone for NMB-2017

Zone	States/Union Territories
North-west	Jammu and Kashmir, Ladakh
Northeast	Arunachal Pradesh, Assam, Manipur, Tripura, Meghalaya
North	Delhi, Punjab, Chandigarh, Haryana, Uttarakhand, Uttar Pradesh, Himachal Pradesh
West	Rajasthan, Gujrat, Maharashtra
Central	Madhya Pradesh, Jharkhand
East	Bihar, Chhattisgarh, West Bengal, Odisha
South	Karnataka, Goa, Kerala, Tamil Nadu, Andhra Pradesh, Telangana, Pondicherry, Andaman and Nicobar

the district samples within a state were not clustered, we grouped the state into geographical regions and chose a district from each region (e.g., if a state needed three districts, it was grouped into north, south, and central).

A statistician selected two districts randomly within the group (i.e., double the number needed); after a review of local conditions within the chosen district, one of the two districts was purposively sampled.

Each district was also grouped into four geographical regions (north, east, south, and west).

1. Rural—within each region, a statistician randomly chose two villages with a population of around 500. After a review of local conditions, one of the two villages was purposively sampled. This resulted in four villages with a population of around 2,000.
2. Urban—within each region, a statistician chose one town/city. From this list of four towns/cities, one city was purposively chosen after a review of local conditions. Within the chosen town/city, a ward was randomly selected. The selected ward was grouped into four geographical regions (north, east, south, and west). Depending on the size of the CEBs (which are either 500 people or 1,000 people), either two or four wards were randomly selected ensuring that each CEB came from a different geographical region.

All individuals ≥20 years of age in each household of the selected CEB were screened.

Participants

Those individuals in the survey from whom the following data were available were included in the study: height, weight, gender, area (urban or rural), education level, physical activity level, and age.

Data Collection

A total of 2 research associates, 7 zonal coordinators, 35 senior research fellows, and 1,200 data collectors were involved in data collection. Each group was given training on their respective duties.

A questionnaire was presented to each individual surveyed, which asked for the following information.

1. Demographic: age, gender, marital status, education level, socioeconomic status, and occupation.
2. Diabetes risk: family history, physical activity, and prior diagnosis of diabetes (and for how long).
3. Yoga practice, if any, and details of the practice.

The following anthropometric data was also collected: height, weight, and hip/waist circumference. Two blood pressure readings were taken at 5-min intervals.

Criteria for Determining Obesity

The body mass index (BMI) cutoffs proposed by the WHO expert group for Asian populations[18] have been used, which are given in Table 2.

Outcome Variables

The outcome was the proportions of obese (BMI ≥ 25) and not obese (BMI < 25) individuals in various populations: zones, areas (rural/urban), educational levels, physical activity levels, gender, and age (under or over 40 years).

Analysis

Because the survey design involved stratified sampling techniques, the study population was weighted[19] to account for sample selection (design weight) and response rate, which was further calibrated using data from the 2011 Census of India, to yield the final weights. Weighting was calculated for each of the seven regions which formed the units of stratified sampling. Final weights were used as the estimates of all population variables. These variables were expressed as proportions, and *t*-tests were used to calculate *P*-values. Odds ratios (OR) were calculated from a binary logistic regression analysis to examine the association between various factors (age, gender, education level, physical activity level, and urban/rural) and the outcome (obesity). A *P*-value less than 0.5 was deemed to be significant.

Python v3.7 Pandas v0.23 was used to import data, calculate weighting, obesity levels, and all descriptive statistics. SPSS V.26 was used to calculate OR, *P*-values, and to do the binary regression analysis.

Table 2. Classification of Weight by BMI

Classification		BMI
Underweight	Not obese	<18.5
Normal		18.5–22.9
Overweight		23–24.9
Obese	Obese	≥25

Results

Description of Data

A total of 1,00,531 individuals participated in the study. Table 3 and Figures 1 to 6 show participant characteristics.

Table 3. Participant Characteristics and Core Measures

	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m²)
μ ± SD	41.20 ± 13.81	157.89 ± 9.98	61.64 ± 12.91	24.79 ± 5.06
Min	18	96	35	9.90
Max	93	210	160	59.56

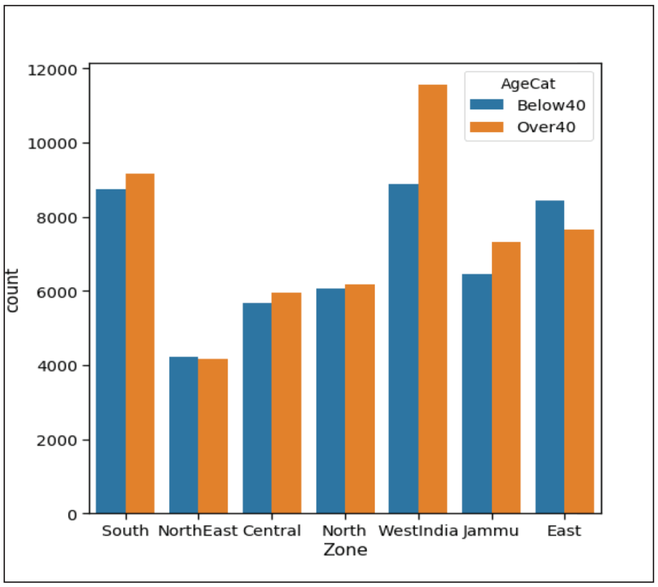

Figure 1. Zonal Distribution by Gender.

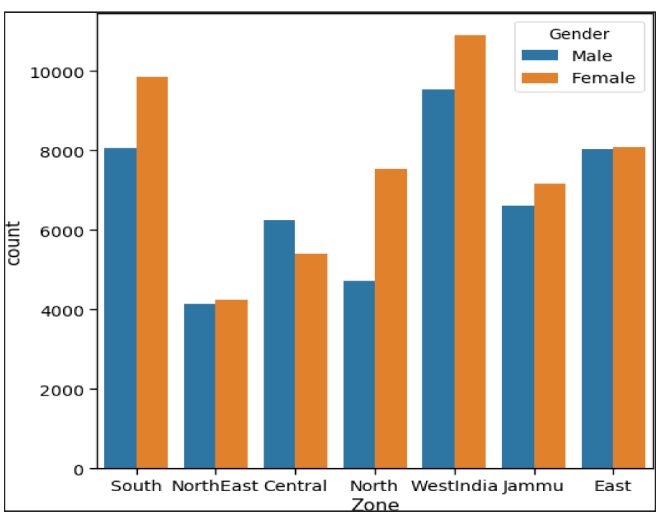

Figure 2. Zonal Distribution by Age.

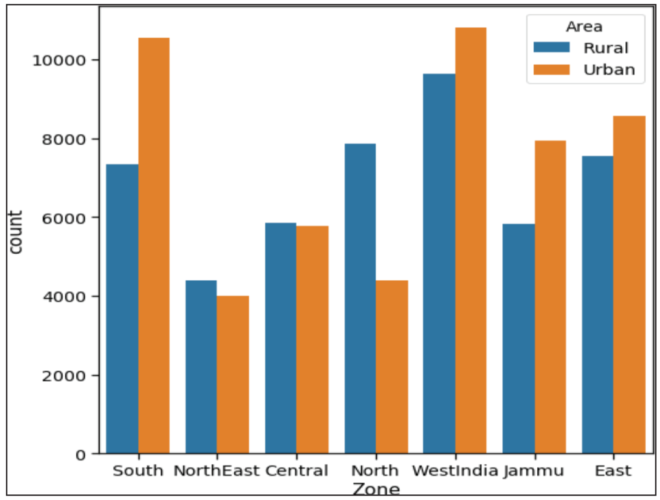

Figure 3. Zonal Distribution by Urban/Rural.

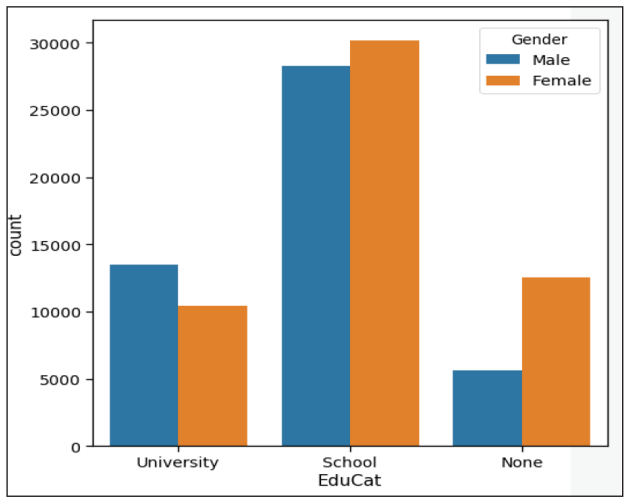

Figure 4. Education Levels by Gender.

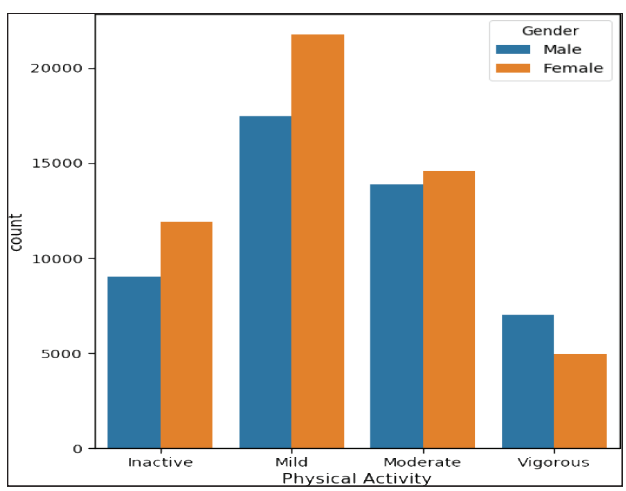

Figure 5. Physical Activity by Gender.

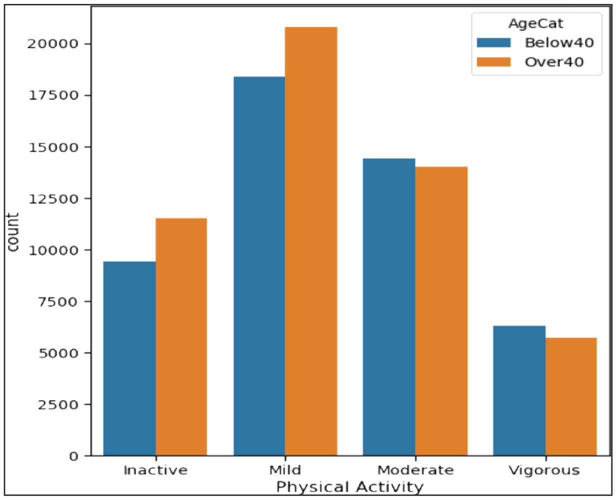

Figure 6. Physical Activity by Age

Prevalence of Obesity Across Various Populations

Table 4 shows the weighted prevalence of obesity in each zone, stratified by age, gender, and urban/rural. The overall prevalence of obesity across India was 40.3% (P < .001). Among regions, obesity was the highest in the south (46.51%) and the lowest in the east (32.96%). Across the country as a whole, obesity tended to be higher among women (41.88%) as compared to men (38.67%), higher in urban regions (44.17%) as compared to rural regions (36.08%), and higher among people over 40 years of age (45.81%) as compared to those under 40 years (34.58%).

We analyzed how obesity varied with physical activity levels and education levels. It was found (the "Total" row in Table 5) that increased education levels were related with increased obesity—university educated individuals tended to be more obese (44.6%) when compared to those with no education (38.4%). Not surprisingly, populations with vigorous physical activity had lower obesity rates (32.56%) than populations that were inactive (43.71%).

We also analyzed how obesity varied when nonmodifiable factors—age and gender—were combined with modifiable factors—physical activity and education levels (Table 5). It was found that in general the effects of modifiable factors exacerbated the effects of nonmodifiable factors. Thus, men with university education had higher levels of obesity than men who were uneducated (55.2% vs. 38.4%). Similarly, among people over 40 years of age, the university educated subpopulation had 55.2% obesity while the uneducated subpopulation had 38.4% obesity.

The final part of the analysis was to determine if the increase in obesity with each of these factors was statistically significant. This was done by running a binary logistic regression analysis on each factor—age, area, educational category, physical activity levels—and determining the OR, along with the associated P-values and CIs. This is shown in Table 6.

Discussion

Phase 1 of NMB-2017 is the only pan-Indian study of obesity, prediabetes, and diabetes. A comparable study, the Indian Council of Medical Research-India Diabetes (ICMR-INDIAB),[20] though quite large, was still limited to 15 states, representing only 51% of India's adult population. Also notable is the fact that several of the extant large-scale reports of obesity prevalence in India[12,21] use the WHO international guidelines[3] for BMI cutoffs to determine obesity, which defines obesity when BMI ≥ 30. However, these guidelines are based on studies of Caucasians who have, when compared with age-matched Asian Indians, lesser total, truncal, intra-abdominal subcutaneous, and ectopic tissue fat at a given level of BMI. It is thus more representative of the Indian

Table 4. Weighted Regional Prevalence of Obesity Across Gender, Area, and Age (P < .001 for Each Proportion, Student's t-test)

	IndiaF		Central		East		Northwest		North		Northeast		South		West	
	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese
Gender																
Female	58.12	41.88	63.66	36.34	66.7	33.3	52.79	47.21	51.52	48.48	62.81	37.19	51.95	48.05	56.43	43.57
Male	61.33	38.67	63.22	36.78	67.39	32.61	60.94	39.06	59.7	40.3	61.71	38.29	55.36	44.64	54.93	45.07
Area																
Rural	63.92	36.08	68.36	31.64	74.4	25.6	60.56	39.44	58.35	41.65	65.02	34.98	57.94	42.06	59.31	40.69
Urban	55.83	44.17	58.43	41.57	60.57	39.43	53.86	46.14	48.07	51.93	59.27	40.73	50.38	49.62	52.54	47.46
Age																
Under 40	65.42	34.58	70.17	29.83	71.35	28.65	62.33	37.67	63.03	36.97	67.31	32.69	58.07	41.93	65.12	34.88
Over 40	54.19	45.81	56.99	43.01	62.3	37.7	51.73	48.27	46.46	53.54	57.15	42.85	49.12	50.88	48.51	51.49
Total	59.68	40.32	63.42	36.58	67.04	32.96	56.7	43.3	54.67	45.33	62.27	37.73	53.49	46.51	55.73	44.27

Table 5. Weighted Prevalence of Oobesity Across Nonmodifiable (Gender and Age) and Modifiable (Education Level and Physical Activity) Factors ($P < .001$ for Each Proportion, Student's *t*-test)

	Education Level						Physical Activity Level							
	None		School		University		Vigorous		Moderate		Mild		Inactive	
	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese	Not Obese	Obese
Gender														
Female	58.45	41.55	58.11	41.89	57.75	42.25	67.42	32.58	61.22	38.78	55.29	44.71	53.91	46.09
Male	68.30	31.70	63.28	36.72	53.68	46.32	67.45	32.55	63.85	36.15	57.99	42.01	59.02	40.98
Age														
Under 40	65.12	34.88	66.91	33.09	62.04	37.96	72.08	27.92	67.47	32.53	62.65	37.35	62.77	37.23
Over 40	60.13	39.87	54.58	45.42	44.80	55.20	62.41	37.59	57.34	42.66	51.11	48.89	50.67	49.33
Total	61.6	38.4	60.66	39.34	55.4	44.6	67.44	32.56	62.5	37.5	56.54	43.46	56.29	43.71

Table 6. Odds Ratio (OR) for Obesity Among Levels of Various Factors

Factor	Level	OR	95% CI for OR (Lower, Upper)	*P*-Value
Age	Under 40	1.0		
	Above 40	1.567	(1.530, 1.605)	<.001
Area	Rural	1.0		
	Urban	1.302	(1.272, 1.332)	<.001
Gender	Male	1.0		
	Female	1.202	(1.175, 1.230)	<.001
Education level	None	1.0		
	Highschool	1.121	(1.084, 1.158)	<.001
	University	1.398	(1.344, 1.455)	<.001
Physical activity	Vigorous	1.0		
	Moderate	3.155	(2.502, 3.978)	<.001
	Mild	3.839	(3.045, 4.840)	<.001
	Inactive	3.833	(3.036, 4.839)	<.001

population when obesity is determined at the lower cutoff levels as recommended by the WHO expert group.[13] Our study provides the first pan-Indian obesity prevalence estimate based on these lower BMI cutoffs. As noted in a consensus statement from more than 100 Indian medical experts representing reputed medical institutions, hospitals, government-funded research institutions, and policy-making bodies in 2009,[22] the lower cutoffs are going to result in additional 10% to 15% of the Indian population to be labeled as overweight/obese. However, they also noted that the application of these guidelines will result in a "deceleration effect on the escalating problem of type 2 diabetes and cardiovascular disease."[23]

Our results have shown that obesity is a highly prevalent condition across the country, with 40.32% of the estimated weighted prevalence among adults 18 to 80 years of age. Southern India (46.51%) shows the highest prevalence, while eastern India shows the lowest (32.96%). Among other regions, north, west, and northwest are all well above the national average, showing a respective prevalence of 45.33%, 44.27%, and 43.3%; while northeast and central regions are well below the national average, with a respective prevalence of 37.73% and 36.58%.

Levels of urbanization can be the reason for the lower prevalence in the east, northeast, and central regions as compared to the others.[24,25] As seen in Table 6, urban populations have 1.3 times higher odds of being obese compared to their rural counterparts. East, northeast, and central are the three least urbanized regions in India.[26] Our results show that the urban population is markedly more obese than the rural population—44.17% vs. 36.08%. These findings are just as true at the zonal level as they are at the national level. In fact, our results show that even in zones where obesity is markedly less than the national average, the urban population exhibits a high prevalence of obesity. For example, the eastern zone whose overall prevalence is 32.96% has an urban prevalence of 39.43%, which is very close to the national average. This provides public health authorities many opportunities for evolving effective policies, for instance through adult education, early intervention in urban schools, etc.

Our study results highlight the importance of both nonmodifiable (age and gender) and modifiable (education levels and physical activity levels) factors for determining obesity. The population above 40 years of age are more obese (45.81%) while those under 40 years are less so (34.58%). In addition to age, gender is another determinant of obesity, with women showing a higher prevalence (41.88%) as compared to men (38.67%).

Obesity is higher among the educated than among the uneducated: 44.6% among those with college education as compared to 38.4% among those with no education. This is contrary to the findings in other regions of the world. For example, researchers have reported decreasing obesity with the number of years of education in Australia, Canada, and England.[27] But, as noted by Cohen et al.,[28] this inverse relationship between educational attainment and obesity has only been documented in higher-income countries; they point out that lower-income countries have the opposite relationship, with higher educational attainment being related to increased levels of obesity. The cause of this "education penalty" in lower-income countries is likely to be multifactorial in nature and needs further research. At any rate, the education penalty is more pronounced in the urban population (46.65% of urban adults with university-level education are obese) as compared to the rural population (35.71% of rural adults with university-level education are obese).

Not unexpectedly, we find that physical activity is a strong determinant of obesity (32.56% among people who do vigorous physical activity vs. 43.71% among those who do not do any physical activity). Animal models on obesity and other problems may also need to be tested and explored.[29–43] While the percentages are certainly compelling, we see the efficacy of physical activity even more clearly when we look at the OR data. As seen in Table 6, the odds of being obese increases by a factor of 3.8 in inactive persons as compared to those who do vigorous activity. In fact, Table 6 also demonstrates that the level of physical activity is the strongest determinant of whether one is obese or not, even stronger than age (OR = 1.6).

Finally, we note that these factors—age, gender, urban/rural, education level, and physical activity level—combine to exacerbate the prevalence of obesity. For example, obesity is at 58.1% among inactive urban dwellers with university-level education who are over 40 years of age, while it is 25.38% among vigorously active rural dwellers with school-level education who are under 40 years of age. These findings will be of great help in forming very targeted public policies aimed at very specific subpopulations for efficiently addressing the obesity crisis.

The strengths of our study are the pan-Indian nature, a very large representative population, and a multifactorial analysis of obesity. A major limitation of the study is that it did not take diet and stress into account. However, the large sample size and the sophisticated randomization built into the study design have ensured that these factors, though not part of the analysis, are nonetheless unlikely to confound these results. Additionally, many other resources and herbs need to be explored and incorporated for people's well-being,[25,44–47] which may help interventions to be cost-effective.

Conclusion

The high prevalence of obesity found by this study makes the observation by the WHO that "obesity is one of the most neglected public health problems"[13] even more applicable to India. The cost of this rapid epidemiological transition is not limited to the comorbidities of type 2 diabetes and cardiovascular disease. Given the new evidence indicative of a three-fold increase in the risk of developing AD among obese populations without type 2 diabetes,[8] and a potential modeling of AD itself as a brain-specific form of diabetes—the so-called type 3 diabetes,[9] this represents a potentially large neurological dimension to the malady of obesity. Given the high cost of obesity in terms of type 2 diabetes, cardiovascular diseases, and AD, urgent public health measures are necessary to reduce its impact.

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Author Contribution

Murali Venkatrao conceptualized stratified analysis methodology, performed sample analysis, and wrote the manuscript. Dr Raghuram Nagarathna being the primary investigator and the guarantor of this study had full access to all data in the study and taken responsibility for the integrity of the data and its analysis. Dr Suchitra Patil performed additional analysis. Dr Vijaya Majumdar and Dr Sunanda Rathi oversaw the planning, data collection, and participant supervision at the study sites. Dr Hongasandra Nagendra conceptualized the study and monitored its execution.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Statement

Ethical clearance was obtained by the Ethics Committee of the Indian Yoga Association. The study was registered on CTRI

(Registration Number—Trial REF/2018/02/017724). This article complies with International Committee of Medical Journal Editors' (ICMJE) uniform requirements for manuscript.

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