Human Biology Review (ISSN 22774424) 10(1) 2021
Original scientific paper (Roy et al. 34-49)
Modified and Accepted on November 11, 2021

Prevalence of normal weight central obesity among apparently healthy Rajbanshi adult males

S. Roy[1], S. Roy[2], A. Khatun[3]and J.Sen[4]

Citation: Roy S, Roy S, Khatun A and Sen J. 2021. Prevalence of normal weight central obesity among apparently healthy Rajbanshi adult males. Human Biology Review, 10 (1), 34-49.

[1]Shubham Roy, Ex-Post Graduate Student, Department of Anthropology, University of North Bengal, NBU Campus, Raja Rammohunpur, Darjeeling-734 013, West Bengal, India. E-mail: shubham.zoology@gmail.com
[2]Shreyasi Roy, UGC-NET Senior Research Fellow, Department of Anthropology, University of North Bengal, NBU Campus, Raja Rammohunpur, Darjeeling-734 013, West Bengal, India. E-mail: shreyasiroy93@gmail.com
[3]Dr. Argina Khatun, Assistant Professor, Department of Anthropology, University of North Bengal, Raja Rammohunpur, Darjeeling 734 013, West Bengal, India. E-mail:arginakhatun87@gmail.com
[4]Prof. Jaydip Sen, Department of Anthropology, University of North Bengal, Raja Rammohunpur, Darjeeling-734 013, West Bengal, India. E-mail:jaydipsen@rediffmail.com

Corresponding Author: Prof.Jaydip Sen, Department of Anthropology, University of North Bengal, NBU Campus, Raja Rammohunpur, Darjeeling-734 013, West Bengal, India. E-mail: jaydipsen@rediffmail.com (M)+91-99322-68224

ABSTRACT

Background: *Obesity confers a significant threat on the cardio-metabolic health of individuals. Obesity is measured in terms of general obesity and central obesity. People generally have acquaintance with the term 'Body Mass Index' or BMI and are, therefore, more aware of maintaining their normal BMI. Nevertheless, they put little emphasis on the concept of 'central obesity'. This has triggered a health risk as several studies have found that people with normal BMI can be centrally obese. This recommends an assessment of central obesity among individuals with normal BMI. As a consequence, a concept called 'normal weight central obesity' (NWCO) was developed.*

Methods: *The present study was conducted among 300 adult Rajbanshi males aged between 21-30 years residing under Siliguri sub-division of Darjeeling district, West Bengal, India. Anthropometric measurements such as height, weight, waist circumference (WC) and hip circumference were taken. Prevalence of generalised obesity (in terms of BMI), central obesity [in terms of WC, waist-hip ratio (WHR), waist-height ratio (WHtR) and conicity index (CI)] and NWCO were evaluated.*

Results: *Based on BMI cut-offs for Asian population, the sample consisted of 1% underweight, 35.6% normal, 35.34% overweight, 23.6% obese and 4.3% very obese subjects. Prevalence of centrally obese subjects were 25%, 61%, 65% and 43% based on WC, WHR, WHtR and CI respectively. The studied sample size exhibited 10.28%, 45.79%, 41.12% and 46.72% of NWCO (where central obesity was measured in terms of WC, WHR, WHtR and CI respectively).*

Conclusion: *The present study exhibited moderate prevalence of NWCO. Assessment of central obesity in addition to BMI must be encouraged in all clinical settings.*

Keywords: *normal weight central obesity, Rajbanshi males, NWCO*

INTRODUCTION

Obesity is one of the most common, yet among the most neglected, public health problems in both developed and developing countries (WHO, 2000a). It is a major modifiable cardiovascular risk factor stated by American Heart Association (Eckel and Krauss, 1998). According to World Health Organization (WHO) fact sheets, worldwide prevalence of obesity has tripled since 1975. It was found that in 2016 that more than 1.9 billion adults (of 18 years and older) were overweight and of these over 650 million were obese. Speaking in terms of percentages, it was revealed that 39% of adults (≥18 years) were overweight in 2016, and 13% were obese. Obesity is generally classified into generalised obesity and central obesity. Both general obesity and central obesity are associated with increased risk of morbidity and mortality (Mogre et al. 2014).General obesity is measured in terms of body mass index (BMI) whereas central obesity (also called abdominal obesity) is measured in terms of waist circumference (WC), waist-hip ratio (WHR), waist-height ratio (WHtR) and conicity index (CI).

How significant is central obesity and normal weight central obesity?

Although BMI is widely used to measure obesity, relying solely on BMI would be misleading in estimating high-risk populations. This is because BMI often results in misclassification and underestimation of population who could be centrally obese (Ashwell and Gibson, 2009 and 2014).There is consensus that an anthropometric measure of central obesity is a better predictor of cardio-metabolic risk, diabetes risk, and all-cause mortality than BMI is, and that combining the 2 indices might be even better (Bosomworth, 2019).As a consequence, several international health organizations such as National Institute for Health and Clinical Excellence (NICE, 2006) and the National Heart, Lung and Blood Institute (NHLBI, 1998) have recommended the addition of anthropometric indicators of central obesity to BMI in all clinical assessments. Several studies have also recommended the assessment of central obesity even among individuals with normal BMI (Ashwell et al., 2016; Thaikruea and Thammasarot, 2016). The concept of normal weight central obesity (NWCO) or ‘isolated abdominal obesity’ was thus developed and was defined as central obesity in participants with normal weight (by BMI). The prevalence and association of NWCO with long-term health outcomes are studied in different regions of the world, as portrayed in **Table 1**:

Table 1. Findings of some studies involving NWCO

Study	Country	Subjects	Findings
Sahakyan et al., 2015	Third National Health and Nutrition Examination Survey (NHANES), US	Adult population aged 18-90 years	NWCO (central obesity defined by WHR) is associated with greater cardiovascular risk and mortality than BMI-defined obesity, particularly in the absence of central fat distribution.
Sharma et al., 2016	-	Older adults (aged ≥65 years) with coronary artery disease	NWCO (central obesity defined by high WC and WHR) demonstrated higher mortality risk.
Thaikruea and Thammasarot, 2016	Thailand	Health care providers	NWCO group was more likely to have more cardiovascular disease risk factors compared to normal weight group.
Owolabi et al., 2017	South Africa	Adults (age ≥18 years) attending health care facilities	One in three adults of normal weight had central obesity.
Shirasawa et al., 2019	Japan	Adults aged 40-64 years	NWCO was associated with cardiovascular disease risk factors, such as hypertension, dyslipidemia, and diabetes, compared with normal weight without central obesity, regardless of sex.
Sun et al., 2019	United States	Post-menopausal women (age 50-79 years)	NWCO in women was associated with excess risk of mortality, similar to that of women with BMI-defined obesity with central obesity.

The findings of several studies (**Table 1**) conclude the importance of awareness of the prevalence, assessment and prevention of NWCO. The phenomenon could be higher among Asian Indians as they have a greater predisposition of central obesity and accumulation of visceral fat (Joshi, 2003). To the best knowledge of the authors, there is a dearth of studies on the prevalence of NWCO in India. However, several studies were found to claim that prevalence of central obesity to be much higher compared to general obesity. According to ICMR-INDIAB study 2015, prevalence rate of central obesity (ranging from 16.9%–36.3%) was found to be higher than that of general obesity (ranging from 11.8% -31.3%) (Pradeepa et al., 2015). In a study in West Bengal, 22.4% and 30.4% were found to overweight and obese based on WHO BMI cut-offs. However, the study exhibited 46.5% and 78.6% of centrally obese subjects based on WC and WHR respectively (Karmakar et al., 2019). Bhardwaj et al., (2011) reported overall prevalence of generalised obesity to be 50.1% and that of central obesity (by WC) to be 68.9%. In another study, the age standardized prevalence of generalized obesity was 45.9% while that of abdominal obesity was 46.6% (Deepa et al., 2009).The higher prevalence of central obesity compared to generalised obesity definitely indicates that individuals with normal BMI may be centrally obese. This calls for a mandatory assessment of central obesity in addition to BMI in all clinical settings.

Why are young adult males chosen as subjects for the present study?

Significant lifestyle changes take place in majority of young adult males such as leaving home, going to university/college, starting work, developing relationships, possibly cohabiting or marrying and parenting (Butler et al., 2004; Burke et al., 2002 and 2004). Such transition in life style leads to energy imbalance which eventually causes weight gain (Poobalan and Aucott, 2016). Improved living conditions gifted us the opportunity to have access to all sorts of facilities which, in turn, resulting to sedentary lifestyles such as riding two-wheelers instead of walking or cycling, often sitting or lying down while engaged in an activity like reading, socializing, watching television, playing video games, or using a mobile phone/computer for much of the day (Unnikrishnan et al., 2012). Additionally, young males who work or study outside prefer to binge on high energy density foods such as pizza, burger, etc. Such foods are preferred as they are of low cost and readily available. However, these foods are likely to contain added sugars and excess vegetable fats which contribute to the occurrence of obesity among young males. All the above factors show that how the young adult males are prone to obesity. This has urged the authors to choose this specific group of population. Keeping all the issues in mind, the present study aimed to report the prevalence of central obesity in a sample

of apparently healthy Rajbanshi adult males and to highlight the importance of NWCO awareness.

MATERIALS AND METHODS

Source of data

The present study was conducted among 300 adult Rajbanshi males aged between 21-30 years residing under Siliguri sub-division of Darjeeling district, West Bengal, India. The nature of the Rajbanshi population could be found in several studies (Sen et al., 2015; Sinha et al., 2018). The minimum number of sample size required for reliable estimate and assessment of nutritional status was calculated utilizing the standard sample size estimation procedure of Lwanga and Lemeshow (1991). In this method, the anticipated population proportion of 50%, absolute precision of 5% and confidence interval of 90% were considered. The minimum sample size for this study was estimated to be 271 individuals. The final sample size was much higher than this estimated size. The study was in accordance with the ethical guidelines for human experimental research as laid down in the Helsinki Declaration (Touitou et al. 2004). Permission was taken from the Institutional Research Board of the University.

Types of data recorded

The anthropometric measurements were recorded following the standard techniques of Singh and Bhasin (1989).Height of the subjects was measured with the aid of anthropometer rod (GPM type, Galaxy Informatics, New Delhi) to the nearest 0.1 cm. Their body weight was recorded (with minimal clothing) using a portable weighing machine (Libra$^{@}$, Edryl-India, Tiswadi, Goa) to the nearest 0.5 kg. WC was taken horizontally to within 0.1 cm, using non-stretchable plastic tape measured at midpoint between the costal margin and iliac crest in the mid-axillary line, with the subject standing and at the end of a gentle expiration. HC was measured at the level of greater trochanters, with the legs close together.

BMI, WHR, WHtR and CI were calculated using the following formulae:

$$BMI=weight/height^2, \text{ weight in kg and height in metres}$$

$$WHR= WC/HC, \text{ both WC and HC in cm}$$

$$WHtR= WC/height, \text{ both WC and height in cm}$$

$$CI= WC/\{0.109*\sqrt{(weight/height)}\}, \text{ WC and height in metres, weight in kg.}$$

Here, 0.109 is a constant which results from the conversion of units of volume and mass into units of length (Pintanga and Lessa, 2005).

A most commonly used indicator of precision or rather accuracy index (Perini et al., 2005) called Technical Error of Measurement (TEM) was utilized. For the calculation of inter-observer TEM, height, weight, WC and HC were recorded from 50 subjects, other than those selected for the study. The measurements were taken thrice on each individual by the first and second authors (SR and SR). The TEM was calculated by the formula:

$TEM=\sqrt{(\sum D^2/2N)}$, where D=difference between the measurements and N= number of individuals measured (Goto and Mascie-Taylor, 2007).

The coefficient of reliability (R) which estimates the proportion of variance in a measured population (that is free from measurement error) was subsequently measured by the following equation:

$R= \{1-(TEM)^2/ SD^2\}$, SD=standard deviation of the measurements

Very high values of R (> 0.975) were obtained for the intra-observer TEM analysis. All the values of R were appreciably higher than the accepted cut-off value of 0.95 as suggested by Ulijaszek and Kerr (1999). Hence, the anthropometric measurements recorded were considered to be reliable and reproducible and the TEM values were not incorporated for further statistical consideration. Finally, the data obtained in the present study was statistically analyzed using statistical constants and relevant statistical tests. The statistical analyses were performed utilizing the software named Statistical Package for Social Science (IBM SPSS, version 23.0, SPSS Inc., Chicago, IL) and a p value <0.05 and <0.001 were considered as statistically significant. Descriptive statistics was utilized to yield overall mean of the anthropometric variables recorded.

The population-specific proposed BMI cut-offs for Asian populations (WHO, 2000b) was used to determine the frequency of general obesity (**Table 2**). To determine the frequency of central obesity, following standard cut-offs were used (**Table 3**).

Table 2. BMI cut-off levels for Asian population

BMI categories	Cut-offs levels
Underweight	<18.5 kg/m^2
Normal	18.5-22.99 kg/m^2
Overweight	23.00-24.99 kg/m^2
Obese	≥25.00-29.99 kg/m^2
Very obese	≥30.00 kg/m^2

Table 3. Standard cut-offs of anthropometric indicators indicating central obesity (for males)

Variables	Cut-offs (for males)	Reference
WC	≥90 cm	WHO, 2008
WHR	>0.95	WHO, 1989
WHtR	≥0.5	Hsieh and Muto, 2004
CI	≥1.25	Flora et al., 2009

RESULTS

The descriptive statistics of the recorded and calculated variables are depicted in **Table 4**. The overall mean age was found to be 25.55±2.87 years. The overall mean height, weight, WC, HC, BMI, WHR, WHtR and CI were found to be 166.66±3.77 cm, 66.49±7.62 kg, 85.59±5.97 cm, 95.10±5.78 cm, 23.94±2.66 kg/m^2, 0.90±0.03, 0.513±0.036 and 1.246±0.080 respectively.

Table 4. Overall mean±SD of the recorded variables in Rajbanshi adult males

Variables	Overall mean
Age (in years)	25.55±2.87
Height (in cm)	166.66±3.77
Weight (in kg)	66.49±7.62
BMI (kg/m^2)	23.94±2.66
WC (in cm)	85.59±5.97
HC (in cm)	95.10±5.78
WHR	.90±.03
WHtR	.513±.036
CI	1.246±.080

Table 5 depicts trends of baseline characteristics of the subjects with aging. For a better apprehension of the collected data, the subjects have been classified into two age-groups: age-group I consisted of 149 individuals of age <25 and age-group II consisted of 151 individuals of age ≥25. Age group II bears higher mean values of all the variables compared to age group II. The one-way analysis of variance (ANOVA) showed statistical significant differences in age-group wise mean age (F-value=787.728), weight (F-value=29.242), WC (F-value= 65.097), HC (F-value=26.682), BMI (F-value=30.998), WHR (F-value=41.235), WHtR (F-value= 65.074) and CI (F-value= 13.322) ($p<0.001$).

Table 5. Age-group wise descriptive statistics (mean ± SD) of all the recorded variables

Variables	Age groups		F-value
	21 to <25 years	≥25 to 30 years	
Age (in years)	22.52±1.11	27.51±1.71	787.428**
Height (in cm)	166.64±3.77	166.67±3.78	.005
Weight (in kg)	63.66±5.91	68.32±8.04	29.242**
WC (in cm)	82.45±4.97	87.63±5.69	65.097**
HC (in cm)	93.04±5.08	96.43±5.83	26.682**
BMI (in kg/m^2)	22.93±2.02	24.60±2.82	30.998**
WHR	0.88±0.034	0.908±0.205	41.235**
WHtR	0.49±0.028	0.53±0.034	65.074**
CI	1.22±.066	1.26±0.086	13.322**

**p-value<0.001

Based on the BMI cut-offs, 3 (1%) were underweight, 107 (35.6%) were normal, 106 (35.34%) were overweight, 71 (23.6%) were obese and 13 (4.3%) were very obese (Figure 1).

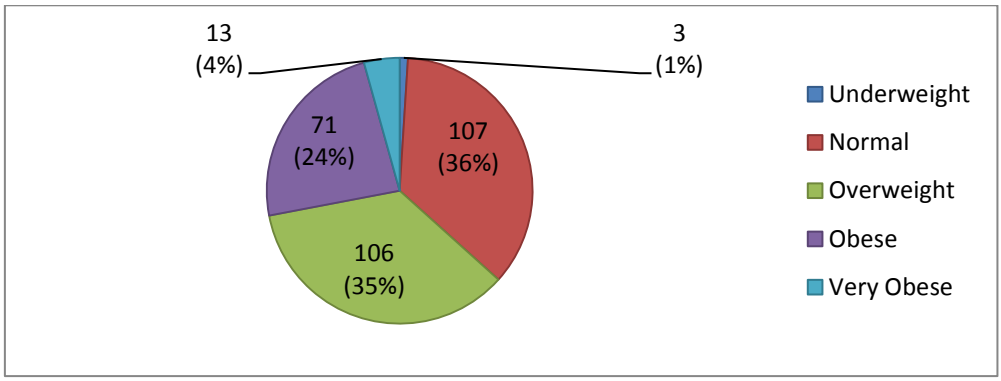

Figure 1. Pie-chart displaying the frequencies of underweight, normal, overweight, obese and very obese subjects

Based on standard cut-offs (**Table 2**), the frequency of centrally obese individuals were displayed in **Figure 2**. 75 (25%), 183 (61%), 195 (65%) and 129 (43%) of the subjects were

found to be centrally obese based on WC, WHR, WHtR and CI respectively. **Table 6** yielded a cross-tabulation showing the distribution of subjects along the gradients of different BMI categories. For easy apprehension, a chart (**Figure 3**) was drawn.

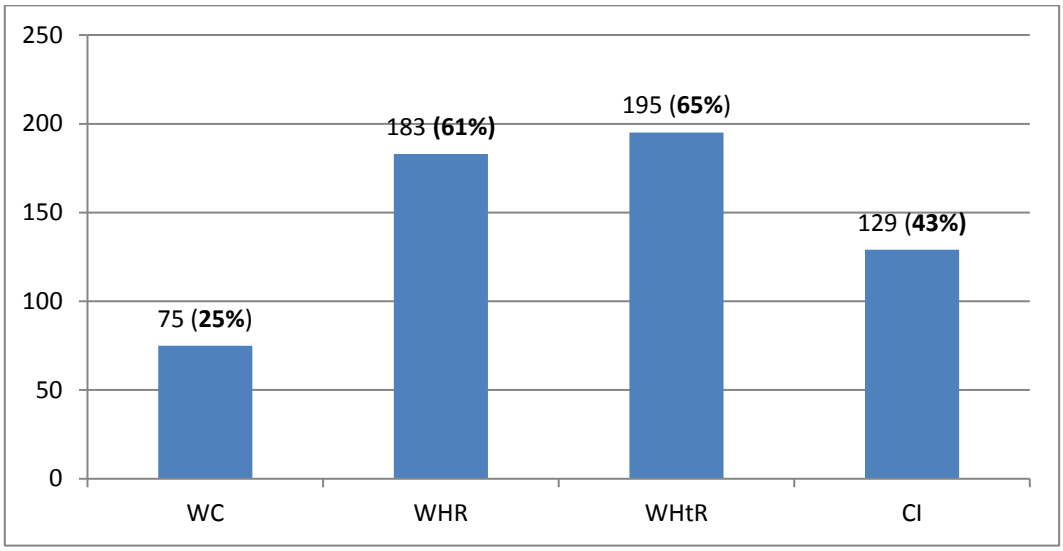

Figure 2. Prevalence of central obesity using different anthropometric indicators

There were 3 (1%) underweight subjects. Out of 107 subjects with normal BMI, 11 had WC≥90 cm whereas remaining 96 had normal WC<90 cm. Based on WHR, 49 out of 107 were centrally obese. Additionally, 44 out of 107 and 50 out of 107 subjects with normal BMI were found to be centrally obese based on WHtR and CI respectively. These subjects fall into the category of NWCO.

Table 6. Frequency distribution of subjects in relation to their nutritional status based on BMI and different anthropometric indicators of central obesity

		Underweight	Normal	Overweight	Obese	Very obese	Total
WC	<90 cm	3	96	82	37	7	225
	≥90 cm	0	11	24	34	6	75
WHR	≤0.90	2	58	35	21	1	117
	>0.90	1	49	71	50	12	183
WHtR	<0.5	3	63	32	6	1	105
	≥0.5	0	44	74	65	12	195
CI	<1.25	1	57	57	43	13	171
	≥1.25	2	50	49	28	0	129
Total		3	107	106	71	13	

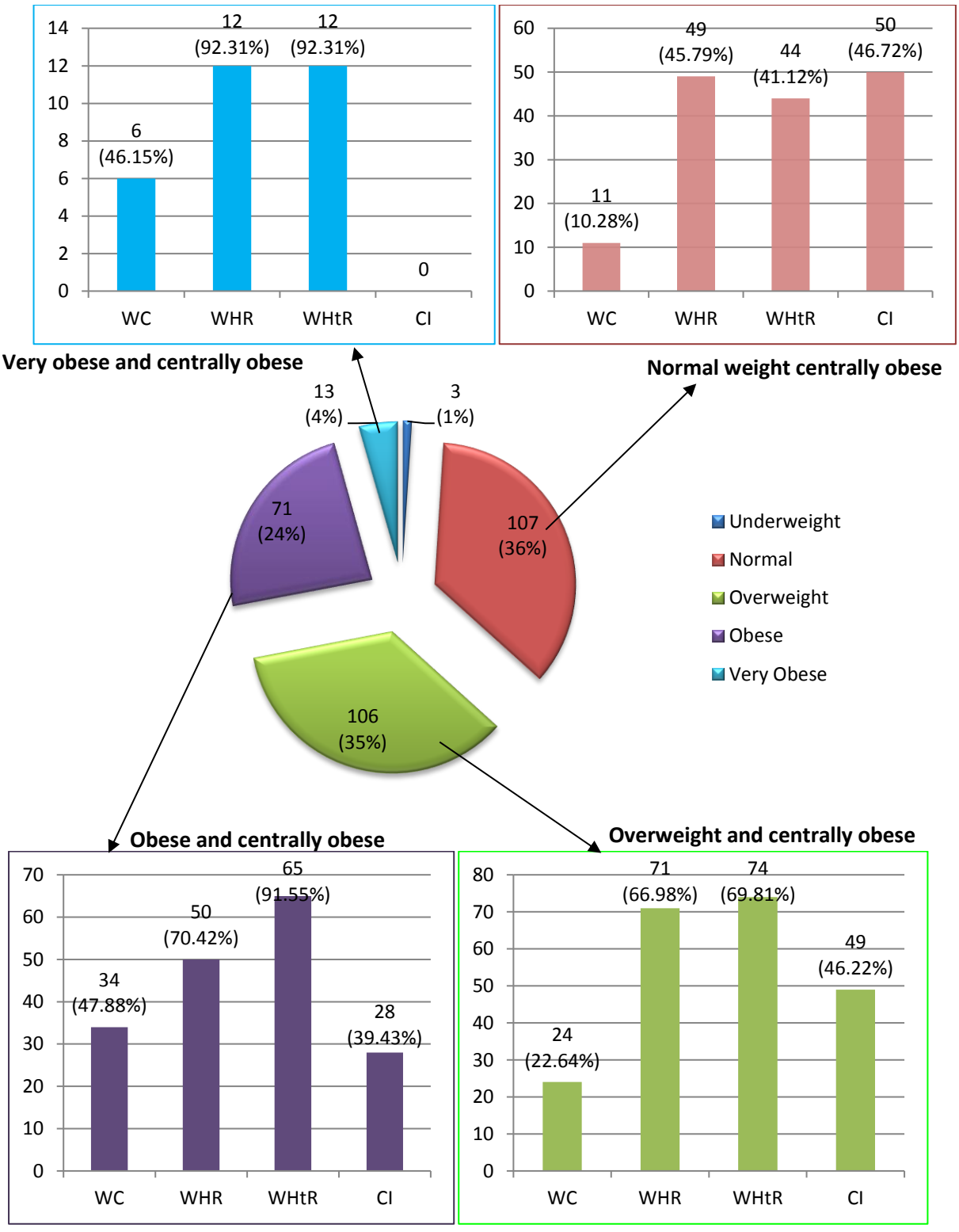

Figure 3. Chart explaining the frequency distribution of subjects in relation to their nutritional status based on BMI and different anthropometric indicators of central obesity

Moving on to the next category of BMI i.e., overweight, it can be observed that out of 106 overweight subjects, frequency of WC-based, WHR-based, WHtR-based and CI-based centrally obese subjects were 24, 71, 74 and 49 respectively. On the flip side of the coin, remaining subjects (though overweight) had normal WC (n=82), WHR (n=35), WHtR (n=32) and CI (n=57). Similar observations could be found in the next two categories of BMI. Out of 71 obese subjects, 34 were WC-based, 50 were WHR-based, 65 were WHtR-based and 28 were CI-based centrally obese. Similarly, out of 13 very obese subjects, 6 were WC-based, 12 were WHR-based, 12 were WHtR-based centrally obese. These subjects fall into the category of 'combined obesity' since they have high BMI and are also centrally obese. Remaining subjects though obese/ very obese had normal WC, WHR, WHtR and CI values. These subjects fall into the category of 'isolated general obesity' since they are centrally non-obese despite being obese/ very obese (by BMI).

DISCUSSION

It is emphasizing that prevalence of general or central obesity varies in the same population or other depending on the cut-off levels used in the studies. In the present study, 300 male subjects (aged 21-30 years) belonging to the Rajbanshi population were chosen. It could be seen that the mean of anthropometric indicators of general obesity (i.e., BMI) and central obesity (i.e., WC, WHR, WHtR, CI) increases with increase in age. This finding is consistent with the findings of Pradeepa et al. (2015). This recommends a crucial inspection in the age-related weight gain (Williams and Woods, 2006).

People are acquainted with the term 'general obesity' or 'BMI'. However, they are least aware of the concept of 'central obesity' or specifically 'NWCO'. In the present study, 107 subjects were found to be with normal BMI (18.5-22.99 kg/m^2). However, the question arises '*do these normal BMI subjects fall within the normal category of anthropometric indicators of central obesity?'* In other words, *'are they centrally non-obese?'* In reply to such query, we get that out of 107 subjects, 11 (10.28%) were found to be centrally obese based on WC. 49 (45.79%), 44 (41.12) and 50 (46.72%) were found to be centrally obese based on WHR, WHtR and CI respectively. Such subjects fall into the category of 'isolated abdominal obesity' where they are centrally obese but are of normal BMI. The prevalence of NWCO in our present study, thus, ranged from 10.28 to 46.72% depending on the criteria used. Irrespective of the defining criteria and other factors, it could be found that our findings are higher compared to other studies (Thaikruea and Thammasarot, 2016: **15.4%, Thailand**; Owolabi et al., 2017: **26.9 to**

36.9%, South Africa; Zhang et al., 2016: **13.9%, China**). In India, there is a dearth of studies on NWCO. The higher prevalence of NWCO in such a small (though adequate) sample size is suggestive of the need to include anthropometric indicators of central obesity in addition to BMI rather than BMI alone. Public awareness should be generated regarding the concept of NWCO. Additionally, awareness regarding 'isolated general obesity' and 'combined obesity' should be generated. The benefits of healthy life style, food habits and physical activity should be promoted by government agencies, doctors and other health professionals. Unnikrishnan et al. (2012) proposed few low-cost, indigenous, appropriate and effective public health strategies such as:

1) **via government**: development of infrastructures such as pavements and parks; implementing exercise and nutrition curriculum in schools.

2) **via society**: encouraging traditional Indian solutions such as yoga, meditation and dance; promoting awareness; advocacy for change in life style.

3) **via non-government organizations (NGOs)**: promoting awareness by community endeavours, using media and classrooms to spread awareness

4) **via family**: limiting portion size, restricting television watching, involving in joint family activities such as walks, picnics and sports.

CONCLUSION

The present study observed high prevalence of central obesity and moderate to high prevalence of NWCO among a small (though adequate) sample size of adult Rajbanshi males. Current public health guidelines for obesity prevention and control is focused on promoting a normal BMI, however, rarely addressing central obesity which is common in the general population. Public awareness must be generated regarding the occurrence of central obesity and NWCO. Assessment of central obesity in addition to BMI must be encouraged in all clinical settings.

ACKNOWLEDGEMENT

The authors acknowledge the financial support extended by the University Grants Commission, Government of India in the form of Senior Research Fellowship [UGC-Ref. No. 617/(NET-JULY 2016)] to the second author (SR).

REFERENCES

Ashwell M, Gibson S. 2009. Waist to height ratio is a simple and effective obesity screening tool for cardiovascular risk factors: analysis of data from the British National Diet and Nutrition Survey of adults aged 19–64 years. *Obes Facts*2:97–103.

Ashwell M, Gibson S. 2014. A proposal for a primary screening tool: 'keep your waist circumference to less than half your height'. *BMC Med* 12:207.

Ashwell M, Gibson S. 2016. Waist-to-height ratio as an indicator of 'early health risk': simpler and more predictive than using a 'matrix' based on BMI and waist circumference. *BMJ Open* 6:e010159.

Bhardwaj S, Misra A, Misra R, et al. 2011. High prevalence of abdominal, intra-abdominal and subcutaneous adiposity and clustering of risk factors among urban Asian Indians in North India. *PLoS One* 6(9):e24362.

Bosomworth NJ. 2019. Normal-weight central obesity: Unique hazard of the toxic waist. *Can Fam Physician* 65(6):399-408.

Burke V, Mori TA, Giangiulio N, et al. 2002. An innovative program for changing health behaviours. *Asia Pac J Clin Nutr* 11 Suppl 3:S586-S597.

Burke V, Beilin LJ, Dunbar D, Kevan M. 2004. Changes in health-related behaviours and cardiovascular risk factors in young adults: associations with living with a partner. *Prev Med* 39(4):722-730.

Butler SM, Black DR, Blue CL, Gretebeck RJ. 2004. Change in diet, physical activity, and body weight in female college freshman. *Am J Health Behav* 28(1):24-32.

Deepa M, Farooq S, Deepa R, Manjula D, Mohan V. 2009. Prevalence and significance of generalized and central body obesity in an urban Asian Indian population in Chennai, India (CURES: 47). *Eur J Clin Nutr* 63(2):259-267.

Eckel RH, Krauss RM. 1998. American Heart Association call to action: obesity as a major risk factor for coronary heart disease. AHA Nutrition Committee. *Circulation* 97(21):2099-2100.

Flora MS, Mascie-Taylor CGN, Rahman M. 2009. Conicity index of adult Bangladeshi population and their socio-demographic characteristics. *Ibrahim Med Coll J* 3:1–8.

Goto R, Mascie-Taylor CGN. 2007. Precision of measurement as a component of human variation. *J Physiol Anthropol* 26: 253-256.

Hsieh SD, Muto T. 2004. A simple and practical index for assessing the risk of metabolic syndrome during the routine health checkups. *Nippon Rinsho* 62:1143–49.

Joshi SR. 2003. Metabolic syndrome--emerging clusters of the Indian phenotype. *J Assoc Physicians India* 51:445-446.

Karmakar N, Pradhan U, Saha I, Ray S, Parthasarathi R, Sinha R. 2019. Overweight and obesity among adults in rural Bengal: A community-based cross-sectional study. *CHRISMED J Health Res* 6:23-9.

Lwanga, SK, Lemeshow S. 1991. Sample size determination in health studies: A Practical Manual. Geneva: World Health Organization.

Mogre V, Nyaba R, Aleyira S. 2014. Lifestyle risk factors of general and abdominal obesity in students of the School of Medicine and Health Science of the University of Development Studies, Tamale, Ghana. *ISRN Obes* 508382:1–10.

NHLBI. 1998.Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report. NHLBI obesity education initiative expert panel on the identification, evaluation, and treatment of obesity in adults. Bethesda, MD: National Heart, Lung, and Blood Institute.

NICE. 2006. National Institute for Health and Clinical Excellence. NICE clinical guideline 43: obesity: guidance on the prevention, identification, assessment and management of overweight and obesity in adults and children. London: National Institute for Health and Clinical Excellence.

Owolabi EO, Ter Goon D, Adeniyi OV. 2017. Central obesity and normal-weight central obesity among adults attending healthcare facilities in Buffalo City Metropolitan Municipality, South Africa: a cross-sectional study. *J Health Popul Nutr* 36: 54.

Perini TA, de Oliveira GL, Ornellas JS, de Oliveira FP. 2005. Technical error of measurement in anthropometry. *Rev Bras Med Esporte* 11: 86-90.

Pitanga FJ, Lessa I. 2005. Anthropometric indexes of obesity as an instrument of screening for high coronary risk in adults in the city of Salvador--Bahia. *Arq Bras Cardiol* 85(1):26-31.

Poobalan A, Aucott L. 2016. Obesity Among Young Adults in Developing Countries: A Systematic Overview. *Curr Obes Rep* 5(1):2-13.

Pradeepa R, Anjana RM, Joshi SR, et al. 2015. Prevalence of generalized & abdominal obesity in urban & rural India--the ICMR-INDIAB Study (Phase-I) [ICMR- NDIAB-3]. *Indian J Med Res* 142(2):139-150.

Sahakyan KR, Somers VK, Rodriguez-Escudero JP, et al. 2015. Normal-Weight Central Obesity: Implications for Total and Cardiovascular Mortality. *Ann Intern Med* 163(11):827-835.

Sen J, Mondal N, Ghosh P. 2015.Upper Arm Composition as an Indicator of Body Composition and Nutritional Status of Adolescent Boys Aged 10-18 Years. *J Nepal Paediatr Soc* 35(2): 152-61.

Sharma S, Batsis JA, Coutinho T, et al. 2016. Normal-Weight Central Obesity and Mortality Risk in Older Adults With Coronary Artery Disease. *Mayo Clin Proc* 91(3):343-351.

Shirasawa T, Ochiai H, Yoshimoto T, et al. 2019. Associations between normal weight central obesity and cardiovascular disease risk factors in Japanese middle-aged adults: a cross-sectional study. *J Health Popul Nutr* 38(1):46.

Singh IP, Bhasin MK. 1989. Anthropometry, Kamla-Raj Enterprises, Delhi.

Sinha I, Pal A, Sen J. 2018. Age and sex variations in anthropometric characteristics and body composition of adults belonging to Rajbanshi population of Darjeeling district, West Bengal. *South Asian Anthropologist* 18(2): 203-13.

Sun Y, Liu B, Snetselaar LG, Wallace RB, Caan BJ, Rohan TE, Neuhouser ML, Shadyab AH, Chlebowski RT, Manson JE, Bao W. 2019. Association of Normal-Weight Central Obesity With All-Cause and Cause-Specific Mortality Among Postmenopausal Women. *JAMA Netw Open* 2(7):e197337.

Thaikruea L, Thammasarot J. 2016. Prevalence of normal weight central obesity among Thai healthcare providers and their association with CVD risk: a cross-sectional study. *Sci Rep* 6:37100.

Touitou Y, Portaluppi F, Smolensky MH, Rensing L. 2004. Ethical principles and standards for the conduct of human and animal biological rhythm research. *Chronobiol Int* 21:161–70.

Ulijaszek SJ, Kerr DA. 1999. Anthropometric measurement error and the assessment of nutritional status. *Br J Nutr* 82:165–177.

Unnikrishnan AG, Kalra S, Garg MK. 2012. Preventing obesity in India: Weighing the options. *Indian J Endocrinol Metab* 16(1):4-6.

WHO. 1989. Measuring obesity: classification and description of anthropometric data. Report on a WHO consultation on the epidemiology of obesity, Warsaw, 21–23 October 1987. Copenhagen: World Health Organization Regional Office for Europe.

WHO. 2000a. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. *World Health Organ Tech Rep Ser* 894: i-253.

World Health Organization (WHO). 2000b.The Asia Pacific Perspective, Redefining obesity and its treatment. Geneva: World Health Organization.

WHO. 2008. Waist circumference and waist-hip ratio: report of a WHO expert consultation. Geneva: World Health Organization.

WHO factsheet. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight accessed on 20th September 2020.

Williams PT, Wood PD. 2006. The effects of changing exercise levels on weight and age-related weight gain. *Int J Obes (Lond)* 30(3):543-551.

Zhang P, Wang R, Gao C, Jiang L, Lv X, Song Y, et al. 2016. Prevalence of central obesity among adults with normal BMI and its association with metabolic diseases in Northeast China. *PLoS One* 11(7):e0160402.