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Relationship of Body Mass Index, Waist Circumference and Waist-Stature Ratio with Body Fat of the Indian Gorkha Population

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ABSTRACT

Introduction: Body mass index (BMI) has traditionally been the chosen indicator by which to measure body size, composition, and to diagnose underweight and overweight. However, alternative measures that reflect abdominal adiposity, such as waist circumference, waist–hip ratio and waist–height ratio, have been suggested as being superior to BMI in predicting cardio-vascular diseases (CVD) risk. This study was aimed at determining the predictive power of anthropometric indicators like body mass index, waist circumference and waist stature ratio with body fat in an Indian military personnel population group, and to establish cut-off points as discriminators of high body fat. **Methods:** The study was cross-sectional in nature with a sample size of 388 active Gorkha male personnel aged 20-49 years (mean age 33.1±5.33). Anthropometric indicators included body mass index, waist circumference, waist-hip ratio and waist-stature ratio. The analysis of receiver operating characteristic curves (ROC) with a confidence interval of 95% was adopted to identify predictors of obesity. Subsequently, the cut-off points with their relevant sensitivities and specificities were identified. **Result:** Areas under the ROC curves with 95% confidence intervals were body mass index = 0.86 (0.84-0.88); waist circumference = 0.82 (0.80-0.84); waist- hip ratio = 0.74 (0.71-0.77); waist-stature ratio = 0.81 (0.78-0.84). Different cut-off points of anthropometric indicators with better predictive power and their relevant sensitivities and specificities were identified. The following cut-offs with their corresponding sensitivity and specificity values are suggested for determining obesity for the study population: body mass index= 23.4 (98.00, 62.00), waist circumference= 77.8 (98.00, 60.50) and waist stature ratio= 0.47 (98.60, 68.00) respectively. **Conclusion:** The results showed that among active military personnel, BMI, WC and WSR may serve well in classifying individuals into broad categories corresponding to percentage fat categories. Further studies on different populations should be undertaken for the verification of the cut-off levels identified.

Key words: Body mass index, cut-off waist circumference, waist-hip ratio, waist-stature ratio

INTRODUCTION

Obesity is a worldwide problem both in developed and developing nations with elevated risk of cardiovascular diseases (CVD) and other chronic conditions (Mokdad *et al.*, 2003; Ogden *et al.*, 2007). Body mass index (BMI) is the usual indicator to

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assess overweight and obesity in population studies, but its validity has been questioned because the index does not measure fat only (Friedl, 2004; Heinrich *et al.* 2008). Such lack of specificity in measuring fat may be a drawback because muscle mass may be a greater component of BMI in the general population. This drawback may be greater in younger than in older persons as muscle mass decreases with age (Gallagher *et al.*, 1996).

In addition, physical performance is highly associated with BMI and also highly associated with maximal performance (Harman & Frykman ,1992). Waist circumference is assessed as part of a gender-specific function to estimate body fat in those who have exceeded their weight allowance (Friedl, 2004; Hodgdon & Friedl, 1999; Williamson *et al.,* 2009; Sundin *et al*., 2011). In one study of obesity among Indian naval hospital staff in the age range of 18 to 47 years, it was reported that the prevalence of overweight / obesity was about 20.66 % by BMI and 47.11% by body fat content (Singh, Sikri & Garg, 2008).

BMI has traditionally been the chosen indicator by which to measure body size, composition, and to diagnose underweight and overweight. However, alternative measures that reflect abdominal adiposity such as waist circumference, waist–hip ratio and waist– height ratio, have been suggested as being superior to BMI in predicting CVD risk.

The aim of this study was to assess which anthropometric parameters best assessed levels of body fat among the population under study. From a policy point of view, we wanted to evaluate whether BMI on its own would be sufficient to assess obesity in the population or whether a combination with waist circumference or waist stature ratio was better in predicting obesity among the population.

METHODS

Active serving Gorkha males (n= 388) aged 20-49 years with a mean age of 33.13 years ± 5.33y and mean BMI of 24.5 kg / m^2 volunteered for the study during 2011. Gorkhas of Tibeto-Mongolian origin mostly belong to the Magar, Rai, Limbu, Gurung, Tamang and Kiranti origin. The Gorkhas are indigenous people mainly from mid-western and eastern Nepal who have gained recognition as tough soldiers in Gorkha regiments of the Indian and British armies (Ember & Ember, 2003). These subjects were part of a larger cohort of a project entitled "Study of Anthropometric, Physiologic and Genomic Diversity among Five Groups of High Altitude Population."

Anthropometric assessment

Height of the subjects was measured to the nearest mm, using SECA 767 electronic personal scale (Medical Scales and Measuring Systems, Germany). Body weight, measured in light clothing and barefoot to the nearest 0.1 kg and height, without shoes, were measured to the nearest 0.1 cm using the SECA 767 electronic personal scale (Medical Scales and Measuring Systems, Germany). BMI was calculated by dividing the subject's weight in kilograms by height in metres squared (kg / m^2). In this study, we have used the BMI classification according to the WHO Classification for Ethnic Asian populations where underweight is <18.50 kg / m^2, normal is 18.50 – 22.99 kg / m^2, overweight is 23.00 – 24.99 kg / m^2, pre obese is 25.00-29.99 kg / m^2 and obese is >30 kg / m^2 (WHO, 2004).

Waist circumference (WC) was measured midway between the iliac crest and the lower-most margin of the ribs. Hip circumference was measured at the maximum circumference of the buttocks, with the subject standing and his feet placed together. The mean of three readings of each circumference was taken for the calculation of the waist: hip ratio. Waist-Hip Ratio (WHR) was calculated by dividing the waist by the hip circumference.

Waist-Stature Ratio (WSR) was measured by dividing waist circumference by standing height in cms.

Biceps, triceps, subscapular and suprailiac skinfold thickness was measured using Eiken skin fold caliper (Eiyoken-Type Meikosha Co Ltd, Japan). Biceps skinfold thickness was measured at the level of the nipple line while triceps skinfold thickness was measured midway between the acromion process of the scapula and the olecranon process. The subscapular and suprailiac skinfold thickness was measured at the inferior angle of the scapula and superiorly on the iliac crest directly in the mid-axillary line respectively. All skinfold thickness was measured to the nearest 1 mm. The mean of three readings was recorded at each site. The sum of all skinfold thickness was used for the calculation of percentage BF using the standard equation (Durnin & Womersley, 1974).

Abdominal obesity is defined as waist circumference $\geq$90 centimeters in men (Ember & Ember, 2003). High waist hip ratio is defined as $\geq$0.9 in men and $\geq$0.85 in women. High WSR is defined as $\geq$0.50 for both males and females. The sum of skinfold thickness is defined as high when the value exceeds 50 mm (Dudeja *et al.*, 2001).

Ethical clearance

The project was approved by the Ethical Committee of the Institute. Informed consent was obtained at initial data collection.

Statistical analysis

The relationship between various anthropometric parameters and body fat was evaluated using Pearson's correlation coefficients and logistic regression was performed for obesity based on 25% body fat with body mass index, waist circumference, waist hip ratio and waist stature ratio. ANOVA was used for comparison of various anthropometric variables of three age groups. Differences between the age groups were analysed by F-ratio and presented as mean±SD. Values were considered statistically significant when $p<$ 0.05. To identify predictors of obesity, we adopted the analysis of receiver operating characteristic curves (ROC) with a confidence interval of 95%. Subsequently, we identified the cut-off points with their relevant sensitivities and specificities. All statistical tests were carried out using SPSS Version 17 for Windows.

RESULTS

All the anthropometric variables between the three age groups showed a statistically significant difference among them, except for height (Table 1). Table 2 shows the correlation matrix between body fat percent with BMI, waist circumference, waist hip ratio and waist-stature ratio. In the present study, about 13.1% of the present population groups under study were obese, having fat percent value of 25% or more (table not shown). In Table 2, using Pearson's correlation coefficients between body fat percent with BMI, waist circumference, waist-hip ratio and waist-stature ratio for the three age groups, body fat percent showed a strong correlation with all anthropometric parameters ($p<0.001$).

Logistic regression analysis in Table 3 shows that those with a high body fat percent and a WC of >85cm were 6.02 times more likely to be obese as compared to those who had a WC of <85cm. However, when age was adjusted, this chance slightly decreased, although it was still statistically significant (OR=4.410, 95% CI 1.84-10.56).

Similarly, those who had a WHR of >0.90 were 6.29 times more likely to be suffering from obesity than those whose WHR was <0.90 (OR 6.29, 95% CI 3.05-12.98) and this chance also decreased slightly when age was adjusted (OR 6.07, 95% CI 2.90-12.69). However, for those who had a WSR >0.50, the chance of being obese compared to those whose WSR <0.50 increased significantly after adjusting for age, it was highly significant (OR 17.03, 95% CI 6.33-45.10).

For those belonging to the higher BMI group (>25kg / m^2), they had a statistically very high chance of being obese than the

Table 1. Anthropometric variables of three age groups (mean and SD).

Variable	*20 – 29 y (n=111)*		*30 – 39 y (n-227)*		*40 - 49 y (n=50)*		*F ratio*	*p*
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*		
Age	26.96	2.06	34.13	2.70	42.32	2.05	718.79	0.000**
Height	164.83	4.54	164.09	5.21	163.55	4.84	1.36	0.26
Weight	63.33	6.41	66.98	6.90	68.70	6.79	15.02	0.000**
Biceps	4.62	2.57	5.26	2.02	5.31	1.65	3.58	0.029*
Triceps	9.27	4.09	11.52	4.20	11.62	3.16	12.37	0.000**
Subscapular	13.94	6.62	16.64	6.43	18.52	7.01	10.17	0.000**
Supra iliac	11.07	5.87	13.49	6.71	12.65	4.65	5.59	0.004*
Fat percent	16.76	5.39	19.68	4.95	20.30	4.25	14.87	0.000**
Sum skinfold	38.91	16.76	46.91	15.91	48.10	12.87	10.82	0.000**
BMI	23.30	2.12	24.88	2.22	25.66	1.99	27.77	0.000**
Waist circumference	76.61	5.12	81.73	6.06	83.90	5.34	39.87	0.000**
Hip circumference	88.41	3.81	90.35	4.13	91.07	5.11	10.28	0.000**
Waist hip ratio	0.87	0.04	0.90	0.05	0.92	0.53	30.42	0.000**
Waist stature ratio	0.46	0.03	0.50	0.04	0.51	0.03	42.80	0.000**

*p< 0.05, **p<0.001

Table 2. Correlation matrix between body fat percent with BMI, waist circumference, waist hip ratio and waist-stature ratio.

		Waist Circumference	*BMI*	*Waist Hip Ratio*	*Waist-Stature Ratio*
Body fat percent	Pearson Correlation	0.759(**)	0.864(**)	0.496(**)	0.774(**)
	Sig. (2-tailed)	0.000	0.000	0.000	0.000
	N	388	388	388	388

** Correlation is significant at the 0.01 level (2-tailed).

Table 3. Logistic regression of the population for obesity based on 25% body fat with BMI, waist circumference, waist-hip ratio and waist-statue ratio.

	Unadjusted				*Adjusted*			
	Sig.	*Exp(B)*	*95 % C.I.*		*Sig.*	*Exp(B)*	*95 % C.I.*	
			Lower	*Upper*			*Lower*	*Upper*
BMI								
<25 kg/m^2	-	-	-	-	-	-	-	-
>25 kg/m^2	0.001	21.25*	7.43	60.41	0.000	22.59*	7.76	65.78
Waist Circumference (WC)								
< 85 cm	-	-	-	-	-	-	-	-
>85 cm	0.001	6.02*	3.23	11.21	0.001	4.410*	1.84	10.56
Waist Hip Ratio (WHR)								
< 0.90	-	-	-	-	-	-	-	-
>0.90	0.001	6.29*	3.05	12.98	0.000	6.07*	2.90	12.69
Waist Stature Ratio (WSR)								
<0.50	-	-	-	-	-	-	-	-
>0.50	0.001	15.02*	5.82	38.79	0.000	17.03*	6.33	45.10

* p<0.05

lower BMI group both in the unadjusted and adjusted groups, respectively (unadjusted OR 21.25, 95% CI 7.43-60.41; adjusted OR 22.59, 95% CI 7.76-65.78).

Table 4 shows the area under the ROC curve between anthropometric indicators like BMI, waist circumference, waist hip ratio and waist stature ratio of obesity and body fat percent. For the 20-29 age group, BMI, WC and WSR showed AUC of more than 0.85. Consistently, among the three age groups, WHR did not show a good AUC. The cut-off points, sensitivity, specificity of anthropometric indicators among three different age groups are also shown in the same table. Except for BMI, the other three anthropometric indicators' cut-off values were found to increase with increasing age in the groups.

Figure 1 show the ROC curve comparing various anthropometric indicators like BMI, waist circumference, waist hip ratio and waist stature ratio to determine obesity based on body fat percent. All four anthropometric parameters indicated a good AUC. BMI, WC and WSR showed AUC of more than 0.85 (0.93, 0.89 and 0.88) respectively (Figure 1).

Table 4. Area under the ROC curve and cut-off points with sensitivity and specificity of anthropometric indicators as prediction of body fat percent among different age groups.

Body Fat percent	*Area under the ROC curve (95%CI)*					
	20-29y	*p*	*30-39y*	*p*	*40-49y*	*p*
BMI (kg/m^2)	0.97 (0.94-0.99)	<0.001*	0.81 (0.78-0.85)	<0.001*	0.89 (0.76- 0.99)	<0.002*
WC (cm)	0.95 (0.93-0.97)	<0.001*	0.77 (0.74-0.80)	<0.001*	0.76 (0.59-0.93)	<0.041*
WHR	0.72 (0.61-0.83)	>0.056	0.72 (0.68-0.76)	<0.001*	0.69 (0.44-0.94)	<0.136*
WSR	0.88 (0.61-0.94)	<0.001*	0.77 (0.74-0.81)	<0.001*	0.80 (0.62- 0.97)	<0.018*

Body Fat percent	20-29y			30-39y			40-49y		
	Cut off point	*Sensitivity (%)*	*Specificity (%)*	*Cut off point*	*Sensitivity (%)*	*Specificity (%)*	*Cut off point*	*Sensitivity (%)*	*Specificity (%)*
BMI (kg/m^2)	22.3	100.00	60.20	23.8	94.70	60.80	22.5	100.00	93.20
WC (cm)	74.4	100.00	62.10	78.9	97.40	60.30	80.8	100.00	68.20
WHR	0.85	85.70	66.00	0.87	94.70	64.60	0.89	66.70	54.50
WSR	0.45	100.00	70.90	0.47	94.70	67.70	0.49	100.00	63.90

* *p*-values for rejecting the null of AUC=0.05

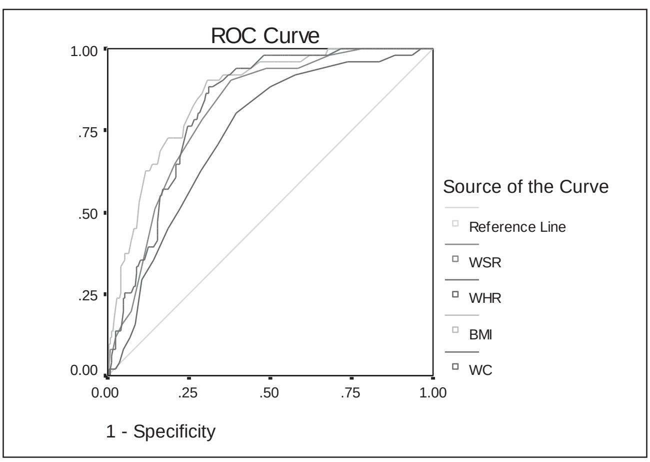

Figure 1. ROC curve comparing various anthropometric indicators used in the study as determinates of obesity. WSR= Waist-Stature Ratio, WHR=Waist-Hip Ratio, BMI=Body Mass Index and WC=Waist Circumference.

Table 5. Area under the ROC curve and 95%CI between anthropometric indicators of obesity and body fat percent for 20-49 years group

Body Fat percent	*Area under the ROC curve (95%CI)*	*p*	*Cut off point*	*Sensitivity (%)*	*Specificity (%)*
BMI (kg/m^2)	0.86 (0.84-0.88)	<0.001*	23.4	98.00	62.00
WC (cm)	0.82 (0.80-0.84)	<0.001*	77.8	98.00	60.50
WHR	0.74 (0.71-0.77)	<0.001*	0.86	94.10	65.60
WSR	0.81 (0.78-0.84)	<0.001*	0.47	98.60	68.00

* p-values for rejecting the null of AUC=0.05

The area under the ROC curve (AUC) and 95% CI, cut-off points, sensitivity, specificity between anthropometric indicators of obesity and body fat percent for 20-49 years are shown in Table 5. It is suggested that the following cut-offs with corresponding sensitivity and specificity be used in determining obesity based on a person's body fat in the present population. BMI= 23.4 (98.00, 62.00), WC= 77.8 (98.00, 60.50) and WSR= 0.47 (98.60, 68.00) respectively.

DISCUSSION

Only the first age group (20-29y) mean WC was within the 78 cm waist circumference as proposed by Misra *et al.* (2006) for Asian Indians (Chang *et al*., 2003). The waist circumference of the 30-39 age group and 40-49 age groups was 81.73 and 83.90 cm respectively. WHO recommends the use of pre-specified cut-off points for BMI, WC and WHR to standardise comparisons within and between populations. Currently such cut-off points are derived from studies among European populations and thus may not be applicable to other ethnic groups. Indeed, some studies suggest that Asian populations manifest CVD risk factors at lower levels of BMI and WC than westerners, owing, in part, to a higher percentage of body fat (Deurenberg-Yap *et al.,* 1999; He *et al.,* 2001; Chang et *al*., 2003). In fact, the WHO Expert Committee on obesity in Asian and Pacific populations suggested revised cutoff points for waist circumference: 90cm for men and 80cm for women to identify persons with abdominal obesity (Misra *et al.*, 2006).

Contrary to common belief, it is not known if BMI is a poorer health measure than waist circumference. Although waist circumference has been preferred over BMI as an assessment of obesity, both perform equally well in their association with known CVD risk factors such as blood pressure and insulin-mediated glucose update (Huxley *et al.,* 2010; Farin, Abbasi & Reaven, 2005). In the present study too, it seems that BMI and waist circumference equally result in high sensitivity and specificity to fat percent.

Limitations

It is always ideal to carry out longitudinal studies for a better understanding of the relationship between anthropometric variables with body fat. But since the subjects of the present study are transferred from one place to another every couple years or so, a longitudinal study was not feasible and the present study was cross-sectional in this regard.

The cut off values suggested for BMI, waist circumference, waist hip ratio and waist stature ratio may not be applicable for a civilian population of the same ethnic group, as the subjects in this study were active serving personnel. The study did not collect information on female subjects.

CONCLUSION

We tried to analyse the relation of BMI, WC, WHR and WSR with body fat in the present study and results show that body fat percent varies across the age groups. The results show that among active military personnel, BMI, WC and WSR may serve well in classifying individuals into broad categories corresponding to percentage fat categories.

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Conflict of interest

The authors declare that there are no competing interests of any kind in this study.

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