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A simple valid tool for measuring obesity-related-CHD risk in Sri Lankan adults

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Summary
Background: The significance of anthropometric measures of obesity that determine coronary-heart-disease (CHD) risk varies among populations. This study compares waist circumference (WC) and body mass index (BMI) in identifying the ''obesity-related-CHD risk'' among Sri Lankan adults.
Methods: A population-based cross-section of 515 adults aged 20—64 years, residing in the district of Colombo in 2004 was selected by a multi-stage, stratified, probability sampling method. WC, height and weight were measured. Demographic, socio-economic and lifestyle characteristics, smoking and obesity-related-CHD risk factors (hypertension, dyslipidaemia, diabetes) were assessed by questionnaires, physical measurements and biochemical assessments. ''Obesity-related CHD risk'' was defined by the presence of $\geqslant$1 obesity-related-CHD risk factors.
Results: Compared to BMI, WC was a stronger correlate of systolic and diastolic blood pressure, triglycerides among both sexes and of plasma glucose among males. It was also an independent predictor of obesity-related-CHD risk in both males (beta co-efficient = 0.046; standard error = 0.013) and females (0.024; 0.012) in contrast to BMI, which was significant only among males (0.138; 0.037) in the logistic regression models adjusted for confounders. At the same level of obesity-related-CHD risk

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corresponding with BMI of 25 kg/m^2 (OR = 1.7) and 30 kg/m^2 (OR = 3.5), the corresponding WC values were 90.5 cm and 105.5 cm for males and 100 cm and 129 cm for females. The derived optimal risk thresholds of WC for identifying obesity-related-CHD risk was 88.5 cm for males and 82 cm for females.
Conclusions: WC with its sex-specific cutoff values can serve as a better screening tool than BMI in identifying individuals at risk of obesity-related CHD in low-resource settings.

Introduction

The relationship of obesity with morbidity and mortality of coronary heart diseases (CHD) has been widely studied in the Framingham Heart Study, Nurses' Health Study and elsewhere [1,2]. Obesity is well known as a predisposing risk factor for conventional risk factors of CHD such as type 2 diabetes mellitus (DM), hypertension (HT) and dyslipidaemia, which have therefore earned the name 'obesity-related-CHD risk factors' [3,4]. In the predisposition of this risk, abdominal (visceral) fat is consistently shown to be more significant than any generalized adiposity [5,6].

A simple anthropometric measure of abdominal obesity is waist circumference (WC) while that of generalized obesity is body mass index (BMI). Current literature shows that both WC and BMI are powerful predictors of individual obesity-related-CHD risk factors [7—9]. This may suggest that these measures are useful as ideal screening tools for identifying ''adults who are at risk of developing CHD'' [10]. This will be particularly of relevance in South Asia, where the natives of South Asian region are more prone to severe degrees of CHD [11,12]. In addition, they are known to have a higher prevalence of abdominal obesity despite having low generalized obesity [13,14].

A major limitation in using any type of anthropometric measurement is the wide variation of their interpretations according to individual characteristics such as gender and physical structure [15]. As such, the obesity-related-CHD risk denoted by anthropometric measurements too may differ among instruments as well as populations [16]. This signifies a need to develop sex and population-specific anthropometric indicators of this risk.

Sri Lanka has recently experienced a rising trend in the prevalence of obesity [17,18]. Furthermore, its previously traditional societies are increasingly predisposed to acquire CHD risk factors and thereby promote CHD [19,20]. Despite its utmost importance, early identification of CHD risk is hampered in Sri Lanka by the high cost of diagnostic tests carried out to detect obesity-related-CHD risk factors. In this respect, to our knowledge, the use of anthropometric measurements as a simple screening tool for detecting an individual's 'obesity-related-CHD risk' has not been explored in Sri Lanka.

The anthropometric measures that are commonly used in clinical or public health settings in Sri Lanka are BMI and WC. In this study, we compared these two measures in the context of their use in identifying the obesity-related-CHD risk in adults in the district of Colombo.

Materials and methods

Study population

The study was set in the district of Colombo, which is the commercial capital of Sri Lanka. Its residents are of diverse socio-economic backgrounds exposed to different patterns of migration and lifestyles. The study population consisted of 515 adults aged 20—64 years who have been residing in the district of Colombo for a continued period of at least one year. Those with pathological or iatrogenic obesity, e.g. hypothyroidism, Cushing syndrome and those with conditions simulating excess abdominal fat, e.g. ascites, pregnancy up to a postpartum period of 3 months were excluded by perusing medical records available with the participants.

Sampling method

A sub-sample of 15 randomly-selected clusters (n = 525) was obtained from a larger population-based prevalence survey of obesity of 40 clusters (n = 1400). Further details on the sampling method and study instruments are given elsewhere [18]. In summary, multi-stage, stratified, probability sampling was carried out to select 40 Grama-Niladari (GN) divisions (smallest administrative units in Sri Lanka of approximately 4000 population) stratified by urban and rural sectors of Colombo district. In each GN division, 35 subjects were randomly iden-

tified by proportions of age and sex representative of the district of Colombo. The 2001 census database and updated electoral registers of Colombo were used as the sampling frames.

Survey methods

Trained teams of one medical graduate and one school leaver with the General Certificate of Education (Advanced Level) qualifications conducted the survey in households. They obtained two recordings of standing height (to the nearest 0.5 cm by microtoise steel tape), body weight (accuracy of ±100 g with an electronic digital weighing scale) and WC (to the nearest 0.2 cm at mid-vertical height from the highest point of iliac crest to the lowest rib margin by non-elastic measuring tape) from each participant in light indoor clothing [21]. They further administered a pre-tested questionnaire to obtain population (demographic, socio-economic) and lifestyle (physical activity, quality of diet, consumption of tobacco and alcohol) characteristics and a drug-history pertaining to HT, DM and dyslipidaemia. A validated food-frequency-questionnaire was used to assess the quality of diet based on scores given to the frequency consumption of energy-dense food and dietary-fiber (overall score >2 = sub-optimal diet; overall score $\leqslant$2 = optimal diet) [22,23]. The International Physical Activity Questionnaire (IPAQ) was culturally validated to assess 'active' and 'insufficiently active' levels of physical activity based on vigorous and moderate physical activities and walking in relation to work, transportation, housework, recreation, sports and leisure time activities during the past week [24].

The teams obtained further information within a week of their initial visit. Using a mercury gauge sphygmomanometer and a standard cuff (12×34 cm), they obtained two recordings of blood pressure (BP), each following a 5 min-rest from all participants. In addition, nursing officers collected blood samples following an overnight fast of 12–14 hours. Samples were analyzed under similar conditions using a Roche/Hitachi 747 analyzer in the Reproductive Biology and Endocrinology laboratory, University of Colombo. Analyses included: total cholesterol (by enzymatic colorimetric test CHOD/PAP method); triglycerides, LDL and HDL cholesterol (after precipitating LDL in the infra-natant with heparin and magnesium chloride); and glucose (by the hexokinase-glucose-6-phosphate-dehydrogenase method).

Ethical clearance for this project was obtained from the Ethical Review Committee of the Faculty of Medicine, University of Colombo.

Quality of data

Anthropometric measurements showed high reliability when assessed in a sub-sample ($n = 70$), against repeat measurements made within two weeks by the principal investigator.

Accuracy of the bio-chemical tests was ensured by: giving written instructions to participants on preparation for blood tests; maintaining blood samples in appropriate temperatures during transport and storage; using pre-validated reagent packs; assay-specific controls to monitor the precision of the analyzer and reagents; and random checks against split-blood samples ($n = 25$). High reliability of the blood tests was demonstrated by obtaining consistent results (Pearson correlation-coefficient > 0.9) for repeat blood tests carried out one week after the initial tests in a sub-sample ($n = 20$).

Definitions of variables

The exposure variables were BMI and WC. The outcome variable was a binary response that indicated the presence or absence of ''obesity-related-CHD risk''. This risk was defined as a participant having $\geqslant$1 obesity-related-CHD risk factors (HT, DM, dyslipidaemia) [25]. HT was defined as systolic BP $\geqslant$140 mmHg and/or diastolic BP $\geqslant$90 mmHg and/or current use of anti-hypertensive drugs. DM was defined as fasting plasma glucose >125 mg/dl and/or current use of insulin or oral-hypoglycaemic drugs [26]. Dyslipidaemia was defined as fasting plasma triglycerides (TG) $\geqslant$200 mg/dl and/or LDL $\geqslant$160 mg/dl and/or HDL <35 mg/dl in males (<45 mg/dl in females) and/or current use of lipid-lowering drugs [21].

Statistical analyses

The analyses were conducted separately for males and females. The use of each anthropometric measure (BMI and WC) in identifying the obesity-related-CHD risk was compared using the following methods:

1. *Compare the associations of BMI and WC with individual obesity-related-CHD risk factors*: Correlations of BMI and WC with plasma glucose, lipids and BP were assessed using Pearson's correlation-coefficient (r) values.
2. *Determine whether BMI AND WC are significant variables in identifying the presence of obesity-related-CHD risk*:

Four logistic regression models were developed with obesity-related-CHD risk as the outcome variable and BMI or WC as the exposure variable. These models were adjusted for potential confounding effects by also including age (20—34; 35—49; 50—64 years); ethnic group (Sinhalese; non-Sinhalese); education (Grade 0—5; Grade 6-Ordinary level Examination; Advanced level Examination and above); income (Rupees <5001; 5001—10,000; >10,000); residence (urban; rural); physical activity (active; insufficiently active) and quality of diet (optimal; sub-optimal) as exposure variables in a stepwise forward LR method [28]. Consumption of tobacco (never; past; current smoker) and alcohol (0—7; 8—14; >14 U of alcohol/week) was also included in models with males. Significance of BMI and WC in identifying obesity-related-CHD risk was assessed by the beta regression-coefficients and standard errors (SE) of BMI and WC in these adjusted models.

3. *Compare the obesity-related-CHD risk at different BMI and WC values*:

Table 1 Relationship of waist circumference (WC) and BMI with obesity-related-CHD risk factor/s among males and females

(1) *Correlation of WC and BMI with individual obesity-related-CHD risk factors*

Individual risk factors	Males (n = 262)		*Females* (n = 253)		Total	
	Mean (SD)[a]	r Value[b]	Mean (SD)[a]	r Value[b]	Mean (SD)[a]	r Value[b]
Systolic BP	128.1 (16.4)		126.6 (16.5)		127.3 (16.4)	
WC		0.29**		0.32**		0.31**
BMI		0.19**		0.29**		0.24**
Diastolic BP	81.6 (13.4)		77.4 (12.3)		79.4 (12.9)	
WC		0.30**		0.27**		0.30**
BMI		0.23**		0.26**		0.24**
Plasma glucose	102.8 (33.7)		101.6 (42.1)		102.2 (38.3)	
WC		0.20**		0.03		0.11*
BMI		0.16*		0.02		0.06
LDL cholesterol	145.0 (50.5)		140.8 (48.2)		142.8 (49.3)	
WC		0.09		0.10		0.10*
BMI		0.11		0.20**		0.16**
Triglycerides	150.9 (66.0)		125.8 (60.1)		137.9 (64.2)	
WC		0.30**		0.31**		0.31**
BMI		0.27**		0.22**		0.23**
HDL cholesterol	43.5 (8.9)		48.0 (10.7)		45.9 (10.2)	
WC		−0.08		−0.09		−0.10*
BMI		−0.11		−0.05		−0.06

(2) *Association of WC and BMI with presence or absence of ⩾1 obesity-related-CHD risk factors*

Anthropometric measure	Mean (SD)[c]	Sig.[d]	Mean (SD)[c]	Sig.[d]	Mean (SD)[c]	Sig.[d]
WC		**		**		**
Presence of ⩾1 factor	89.2 (4.2)		86.4 (4.4)		87.8 (11.9)	
Absence of ⩾1 factor	82.3 (11.5)		82.3 (11.9)		82.3 (11.7)	
BMI		**				**
Presence of ⩾1 factor	24.9 (4.8)		24.7 (4.4)		24.9 (4.6)	
Absence of ⩾1 factor	22.4 (4.2)		24.1 (4.9)		23.3. (4.7)	

[a] Mean (SD) of systolic and diastolic blood pressure (BP) is given in mmHg; plasma glucose in g/dl; cholesterols and triglycerides in mg/dl.

[b] r Values denote the Pearson's correlation coefficients for the association of systolic and diastolic BP, plasma glucose, cholesterol and triglyceride levels with BMI and waist circumference (WC).

[c] Mean (SD) of BMI is given in kg/m^2 and waist circumference (WC) in cm.

[d] The significance of the mean BMI or WC between those with ⩾1 obesity-related-CHD risk factors and those without was assessed using t tests.

* p Value <0.05.

** p Value <0.01.

Compared to the reference values of BMI and WC, odds ratios (OR) for having obesity-related-CHD risk were calculated separately for the BMI and WC values of each participant, using the following formula: Odds Ratio (OR) = exponent[$\beta(X_i - X_{ref})$] [27], where β = regression co-efficient of BMI or WC derived from the logistic regression models; X_i = value of BMI or WC; and X_{ref} = reference point of BMI or WC at the 25th percentile of the study population. Scatter plots were drawn to compare the OR (*Y* axis) with BMI or WC values (*X* axis).

4. *Estimate optimal risk thresholds of BMI and WC that identifies obesity-related-CHD risk*:
Receiver operator characteristic (ROC) curves were drawn for the presence of obesity-related-CHD risk using different threshold values of BMI and WC. The thresholds that maximized the sensitivity and specificity of BMI and WC in detecting this risk were identified as the optimal thresholds of these indicators.

Results

The response rate of the study population was 95.0%. Of the initial 525 selected for the study, 16 did not give consent and were systematically replaced by new subjects of similar age and sex category. Of the final 525 selected, 10 did not attend blood testing. Non-response was predominantly among younger males in urban areas. Of the 515 respondents (262 males), the majority were Sinhalese (91%) and Buddhists (84%). The median age was 38.9 years. Most were educated up to Grade 6-Ordinary Level examination (60%) and earning Rs. 5001—10,000 (59%). These characteristics did not differ significantly between male and female participants ($p > 0.05$) nor with the general population of Colombo district ($p > 0.05$).

Associations of BMI and WC with obesity-related-CHD risk factors

All anthropometric measures demonstrated normal distribution curves. Mean BMI was 24.3 kg/m^2 (SD = 4.7) while mean WC was 85.6 cm (SD = 12.1). Associations of anthropometric measures with obesity-related-CHD risk factor levels are shown in Table 1. Other than HDL cholesterol, mean values of all risk factors were higher among males compared to females. Correlation-coefficients (Pearson *r* values) of BMI and WC were $\leqslant$0.32 with all risk factor levels. However, all risk factor levels except LDL cholesterol correlated slightly better with WC than with BMI. For both measurements, the highest correlation was with diastolic BP among males in contrast to systolic BP among females. Among females, plasma glucose did not correlate significantly with both BMI and WC. Also, the correlations of HDL cholesterol were not significant with either measurement in either sex. It was only TG and BP that correlated well with both measurements in both sexes ($p < 0.01$).

Those with $\geqslant$1 obesity-related-CHD risk factors (61%; 209 with one; 91 with two; and 16 with >2) differed significantly from those without by WC among males and females but only among males by BMI (Table 1).

Significance of BMI and WC in identifying the presence of obesity-related-CHD risk

In the logistic regression models of males, both WC (beta co-efficient = 0.046; SE = 0.013; $p < 0.001$) and BMI (0.138; 0.037; $p < 0.001$) were significant exposure variables that identified the obesity-related-CHD risk as outcome, after adjusting for confounding effects. In the regression models of females, only WC (0.024; 0.012; $p < 0.001$) was a significant exposure variable after adjusting for confounding effects. Other significant exposure variables in the models of both males and females were age, ethnicity and geographical location.

Distribution of obesity-related-CHD risk at different BMI and WC values

The exponential curves of BMI and WC values fitted to their corresponding odds ratios of obesity-related-CHD risk are shown separately for males and females in Fig. 1. Among males, the obesity-related-CHD risk (OR = 1.7) corresponding with a BMI of 25 kg/m^2 almost doubled (OR = 3.5) with a BMI of 30 kg/m^2. At the same levels of risk, the corresponding WC values were 90.5 cm and 105.5 cm among males; 100 cm and 129 cm among females. While the obesity-related-CHD risk was identical for males and females at WC of 80 cm, the risks depicted by similar WC values were higher thereafter for males compared to females.

Optimal risk thresholds of BMI and WC in predicting obesity-related-CHD risk

As shown in ROC curves (Fig. 2), the optimal WC threshold that predicted obesity-related-CHD risk among the males was 88.5 cm with a sensitivity of 55.5% and specificity of 76%. It represented the 54th percentile of the male population with an OR of 1.6. The optimal BMI threshold that

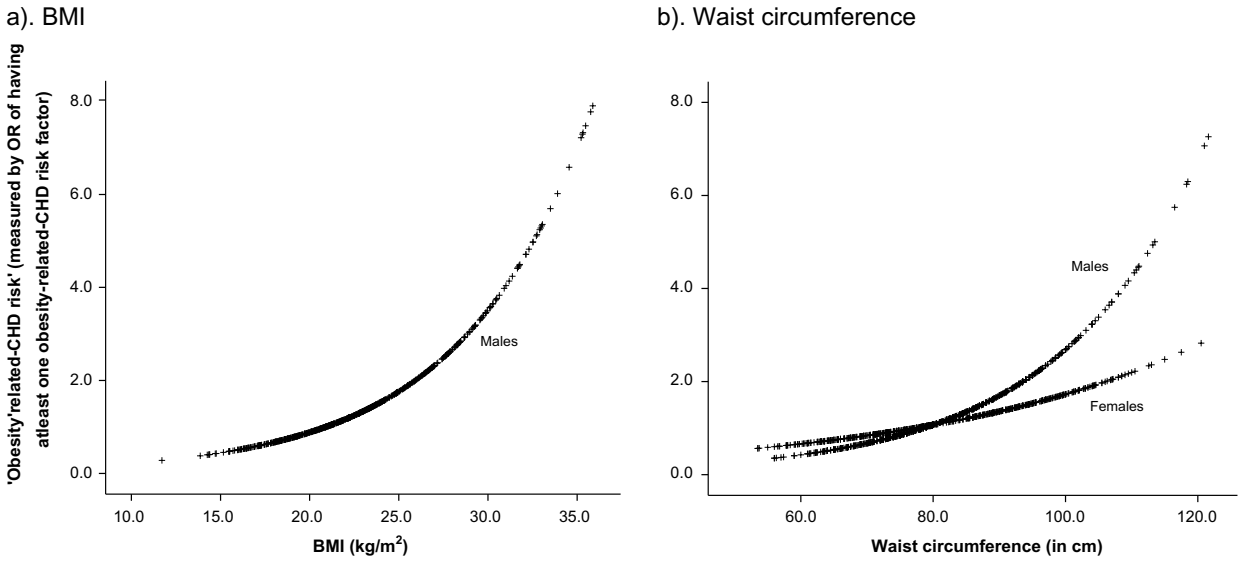

Figure 1 Relationship of anthropometric measures (waist circumference and BMI) with 'obesity-related-CHD risk' (measured by odds ratios for having at least one obesity-related-CHD risk factors) among males and females: (a) BMI and (b) waist circumference. OR (odds ratio) = exponent[$\beta(X_i - X_{ref})$] [27]. Regression coefficients derived from the logistic regression models (β) were: 0.138 (males) for BMI; 0.046 (males) and 0.024 (females) for waist circumference. Reference points at the 25th percentile in the study population (X_{ref}) were: 20.9 kg/m^2 (males) for BMI; 78.5 cm (males) and 77.2 cm (females) for waist circumference.

predicted obesity-related-CHD risk was 23 kg/m^2 with a sensitivity of 61% and specificity of 56.5%, representing the 45th percentile of males with an OR of 1.3. Among females, the optimal WC threshold was 82 cm with a sensitivity of 67.5% and specificity of 52%. It represented the 40th percentile of the female population with an OR of 1.1. The corresponding optimal BMI threshold among them was 24 kg/m^2 with a sensitivity of 56% and specificity of 52%. It represented the 47th percentile of females with an OR of 1.5.

Discussion

Our study demonstrates that WC is a stronger correlate of obesity-related-CHD risk factors as well as a more powerful indicator of 'obesity-related-CHD risk' than BMI. Optimal WC thresholds that identify such a risk are 88.5 cm among males and 82 cm among females.

WC, as a stronger correlate of obesity-related-CHD risk factors than BMI was evident by its slightly higher *r* values as well as significant associations obtained with most of the risk factors (Table 1). This finding is consistent with the results obtained in studies among Caucasians [27—30] and Asians [31]. The stronger correlation of WC seen with TG in both sexes is an expected finding considering the plausible relationship of abdominal obesity with dyslipidaemia in the metabolic syndrome of South Asians. However, despite this relationship and in contrast to some results from Western studies [32], HDL cholesterol did not correlate with both WC and BMI in either sex. This may be due to an improvement in HDL levels among the obese who engage in physical exercise as a strategy for weight reduction. A gender difference was noted as neither BMI nor WC of females correlated with plasma glucose. Our finding was not consistent with the results of some studies [7,27,30—32].

In our study, WC was a significant variable for identifying obesity-related-CHD risk among both males and females in contrast to BMI, which was significant only among males. Similar results were observed in cross-sectional population-based surveys among 25—74 aged Chinese [31] and Singaporean [32] populations. All these studies differ from a US-based study, which demonstrated BMI as a significant predictor in both males and females [27]. This latter study was also not consistent with our findings of a higher risk of obesity-related-CHD noted among males compared to that of females at the same level of WC. Another inconsistency was that the obesity-related-CHD risk denoted by any given BMI or WC level in our study was much higher than that depicted in the US study. For example, BMI $\geqslant$30 kg/m^2 and WC $\geqslant$100 cm denoted an OR = 2.4 for identifying obesity-related-CHD risk among US males. The corresponding ORs from our

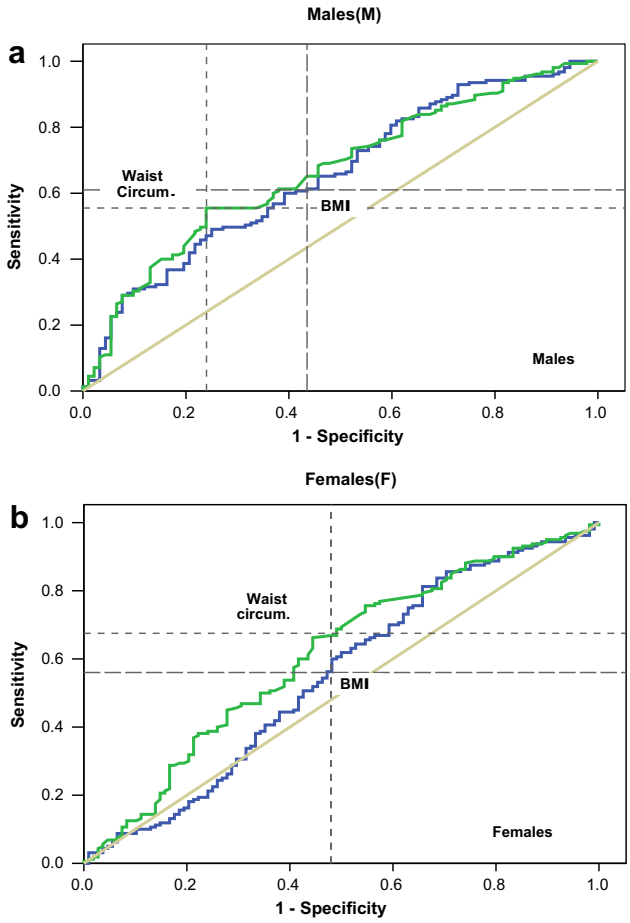

Figure 2 Receiver operator characteristic (ROC) curves of waist circumference and BMI for having obesity-related-CHD risk among males and females: (a) males (M) and (b) females. Area under the curve: BMI: 0.655 (M); 0.548 (F). Waist circumference: 0.669 (M); 0.605 (F).

study (Fig. 1) were 3.5 and 2.7, respectively. In addition to some methodological differences with our study, e.g. confounders considered in the logistic regression models were not identical, the US study included mainly Caucasians aged 20—90 years [27]. This might suggest that different 'origins' of populations could explain some of the variation in the obesity-related-CHD risk associated with anthropometric measures.

The universal WC cutoff value defined by the World Health Organization for detecting abdominal obesity among males of Asian origin is 90 cm [16]. The optimal WC level that indicated obesity-related-CHD risk in our study was lower (88.5 cm). This is of practical value as some cases with obesity-related-CHD risk might go undetected, if they are screened using only the universal cutoff value for WC. A similar result was shown in another study in Taiwan [33]. As for females, they showed a higher optimal WC level (82 cm) compared to their corresponding universal WC cutoff value (80 cm).

Strengths and weaknesses

A major strength of our study lies in obtaining a high response rate in a sample representative of the adults on whom the screening tool would actually be used. It enabled us to derive optimal thresholds of anthropometric measures in a normal population with no over-representation of obese patients or non-obese volunteers [34]. Secondly, we assessed obesity-related-CHD risk using reliable anthropometric measurements that were collected independently. Thirdly, we adjusted this risk for other potential confounding effects of lifestyle and socio-economic factors. In addition, we calculated more accurate estimations of OR using the reference values of BMI and WC derived from a larger cross-sectional survey on the prevalence of obesity.

The principal limitation of this study is due to the limited value of cross-sectional data on WC and BMI in assessing temporal relationships [35],

especially in relation to changes in weight and lifestyles following the diagnoses of HT, DM and dyslipidaemia. Another major weakness of our study was that our risk assessments were based upon a relatively small-sized sample compared to large databases used in other studies [26]. Longitudinal studies on wider population samples are therefore needed to develop more representative WC threshold values for Sri Lankan populations.

Conclusion

This study highlights the use of WC as a screening tool for identifying persons at risk of CHD compared to BMI. It further emphasizes the importance of developing gender and population specific WC threshold values to identify obesity-related-CHD risk.

Higher WC among apparently healthy populations should prompt health professionals to pursue further tests to diagnose HT, DM and dyslipidaemias, which might otherwise be neglected until late presentations. Early identification of these groups will reduce the multiplicative risk arising from a combination of CHD risk factors [15]. WC provides, better than BMI, a valid as well as simple, non-invasive, low cost tool for screening those at risk of CHD, especially in low-resource settings such as in Sri Lanka.

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