# Waist circumference and BMI cut-off points to predict risk factors for metabolic syndrome among outpatients in a district hospital

Mra Aye[1], MBBS, MMSc, Malek Sazali[2], MBBS, MPH

**INTRODUCTION** Metabolic syndrome (MS) is a cluster of risk factors that increases the risk of cardiovascular disease and type 2 diabetes mellitus (DM). Waist circumference (WC), a surrogate indicator of abdominal fat mass, is used to measure central obesity associated with increased risk of hypertension, insulin resistance and type 2 DM, whereas body mass index (BMI) is traditionally used to measure somatic obesity. This study aimed to identify the WC and BMI cut-off points to predict the metabolic risk factors for MS and to determine which is a better predictor.
**METHODS** This was a cross-sectional study conducted over a period of six months. The study involved 355 subjects aged 13–91 years. Youden's index was used to identify the optimal cut-off points.
**RESULTS** The optimal cut-off point of WC to predict individual metabolic risk in females was 84.5–91.0 cm. The BMI cut-off point to predict hypertension and raised fasting blood sugar was 23.7 kg/m$^2$, and that for low level high-density lipoprotein cholesterol was 22.9 kg/m$^2$. For males, the corresponding cut-off points were 86.5–91.0 cm for WC and 20.75–25.5 kg/m$^2$ for BMI, with corresponding sensitivities and specificities. Area under the curve and the odds of developing individual and ≥ 2 metabolic risk factors for MS were higher for WC than for BMI.
**CONCLUSION** WC is a better predictor of metabolic risk factors for developing MS than BMI. Therefore, we propose that metabolic risk factors be screened when WC ≥ 80 cm is found in both genders regardless of BMI.

*Keywords: BMI, metabolic risk factors, metabolic syndrome, waist circumference*
*Singapore Med J 2012; 53(8): 545–550*

## INTRODUCTION

Obesity is a well-known risk factor for developing diabetes mellitus (DM), hypertension, dyslipidaemia and coronary heart disease (CHD).[1-3] The Malaysian National Health Morbidity Survey (NHMS) II (1996) and III (2006) reported an increasing prevalence of obesity from 4.4% to 14.0% and overweight from 16.6% to 29.1% among Malaysians. 29.7% of males were reported to be overweight and 10.0% obese. Women were found to have a higher prevalence of obesity (17.4%) but a slightly lower prevalence of overweight (28.6%).[4] The NHMS reports were based on body mass index (BMI), the conventional method for measuring obesity.[5] Although BMI is commonly used to measure somatic obesity, recent findings have reported its conflicting association with cardiovascular and obesity-related health risks.[6,7] Besides, body fat distribution is another important risk factor for obesity-related diseases. Excess abdominal fat (also known as central or upper body fat) is associated with an increased risk of hypertension, insulin resistance and type 2 DM.[1] Waist circumference (WC) is often used as a surrogate indicator of abdominal fat mass, as it correlates with both subcutaneous and intra-abdominal fat. Several studies have found WC to be an important predictor of DM, CHD and its mortality rate, and clinical tests such as blood pressure, blood glucose and lipoproteins.[1,3,8,9] Cut-off points of WC for health outcomes are affected by demographic variables, including gender and ethnicity.[10-12]

**Table I. Demographic distribution of study samples (n = 355).**

| Variable | No. (%) |
|---|---|
| **Age (yrs)** | |
| 13–19 | 18 (5.1) |
| 20–29 | 35 (9.9) |
| 30–39 | 38 (10.7) |
| 40–49 | 73 (20.0) |
| 50–59 | 100 (28.0) |
| ≥ 60 | 91 (25.0) |
| **Gender** | |
| Male | 174 (49.0) |
| Female | 181 (51.0) |
| **Ethnicity** | |
| Malay | 139 (39.2) |
| Indian | 136 (38.3) |
| Chinese | 80 (22.5) |

Metabolic syndrome (MS) is a cluster of metabolic factors that increases the risk of cardiovascular disease and DM.[2] Presently, there are three sets of criteria for MS: the International Diabetes Federation (IDF), the revised National Cholesterol Education Program (ATP111 NCEP) and the Modified World Health Organization (WHO).[13] MS increases the risk of developing type 2 DM by three-fold and CHD by two-fold,

[1]Department of Medicine, UniKL Royal College of Medicine, Perak, Malaysia, [2]State Health Department, Ministry of Health, Perak, Malaysia
**Correspondence**: Dr Mra Aye, Senior Lecturer, Department of Medicine, UniKL Royal College of Medicine, No. 3 Jalan Greentown, Ipoh 30450, Perak, Malaysia. mraaye@hotmail.com

**Table II. Association of BMI and WC with metabolic risk factors in female and male patients.**

| Variable | Total (n = 355) | Male (n = 174) | Female (n = 181) | p-value | OR (95% CI) |
|---|---|---|---|---|---|
| Age (yrs) | 48.8 ± 15.9 | 51.0 ± 16.3 | 46.7 ± 1.13 | - | - |
| BMI (kg/m²) | 27.5 ± 6.81 | 25.9 ± 5.98 | 28.9 ± 7.44 | 0.01 | 1.84 (1.11–3.07) |
| BMI ≥ 23 kg/m² (%) | 77.7 | 45.7 | 54.3 | - | - |
| BMI ≥ 30 kg/m² (%) | 30.1 | 20.7 | 42.0 | 0.00 | 2.78 (1.73–4.44) |
| Systolic BP (mmHg) | 133 ± 20.3 | 32 ± 20.4 | 132 ± 0.1 | - | - |
| Diastolic BP (mmHg) | 81.6 ± 10.6 | 81.6 ± 11.4 | 81.0 ± 10.7 | - | - |
| Hypertension (%) | 54.1 | 43.8 | 56.3 | 0.04 | 1.55 (1.01–2.36) |
| WC (cm) | 91.8 ± 14.7 | 91.2 ± 13.1 | 92.5 ± 16.0 | | |
| High WC (%) | 62.3 | 35.7 | 64.3 | 0.00 | 4.28 (2.69–6.79) |
| FBS (mmol/L) | 6.61 ± 2.52 | 6.66 ± 2.77 | 6.5 ± 2.29 | - | - |
| High FBS (%) | 54.1 | 53.4 | 49.5 | - | - |
| Diabetes mellitus (%) | 35.8 | 50.4 | 49.6 | - | - |
| HDLC (mmol/L) | 1.12 ± 0.54 | 1.12 ± 0.52 | 1.23 ± 0.51 | - | - |
| Low HDLC (%) | 50.4 | 38.5 | 61.5 | 0.00 | 2.73 (1.77–4.19) |
| TG (mmol/L) | 1.67 ± 1.24 | 1.73 ± 1.42 | 1.68 ± 1.02 | - | - |
| High TG (%) | 37.5 | 48.6 | 41.5 | 0.00 | 2.73 (1.78–4.19) |

Note: Data is presented either as mean ± SD or percentage of patients.
Hypertension: systolic BP ≥ 130 mmHg and diastolic BP ≥ 85 mmHg; high WC: ≥ 90 cm for males and ≥ 80 cm for females; diabetes mellitus: FBS ≥ 7 mmol/L; Low HDLC: < 1.29 mmol/L in females and < 1.03 mmol/L in males; high TG: ≥ 1.7 mmol/L for both genders.
OR: odds ratio; CI: confidence interval; SD: standard deviation; BMI: body mass index; WC: waist circumference; BP: blood pressure; FBS: fasting blood sugar; HDLC: high-density lipoprotein cholesterol; TG: triglycerides

and it has become a major public health challenge around the world.[14] The prevalence of MS is on the rise due to the obesity epidemic.[2] Central obesity is a cardinal feature of MS.[1,15] The pathogenesis of excess abdominal fat distribution causing cardiometabolic diseases is still unknown, although several hypotheses have been proposed.[16-23] WC is a valuable tool in clinical care and public health research to identify individuals who are at a significantly higher risk for obesity-associated diseases.

This study aimed to identify the cut-off points of WC and BMI to predict metabolic risk factors for developing MS as well as to determine which indicator is a better predictor of metabolic risk factors.

## METHODS

This was a cross-sectional study conducted from January 15 to June 30, 2011. Sample size (n = 355) was determined using the Epi Info version 6 (CDC, Atlanta, GA, USA) for population surveys. Samples were selected using clustered systematic randomised sampling, and 15 patients were recruited every week. Every Thursday, the author randomly selected ten patients from the physician's clinic and five others from the outpatient clinic. Inclusion criterion was age ≥ 13 years, while the exclusion criteria were patients with known causes of obesity such as Cushing's and pseudo-Cushing's syndrome, known causes of dyslipidaemia such as chronic renal failure, nephrotic syndrome and hypothyroidism, as well as HIV patients on antiviral drugs.

The research purpose was explained to the participants, and informed consent was obtained from all patients aged ≥ 18 years and from the parents of those aged < 18 years. The patients were interviewed and examined by the investigators. BMI (kg/m²), WC (cm) and blood pressure (mmHg) measurements were carried out by the same assigned staff nurse who was trained to measure WC. The WC measurement was standardised by applying the measuring tape at the midpoint between the lower costal cartilage and the highest point of the iliac crest when the patient exhaled completely. Blood samples for fasting blood sugar (FBS), serum triglyceride (TG) and high-density lipoprotein cholesterol (HDLC) were taken in the early morning after an overnight fast. Samples were defined as high WC (WC ≥ 90 cm for males and ≥ 80 cm for females), normal weight (BMI 18.5–22.9 kg/m²), overweight (BMI 23–29.9 kg/m²) and obese (BMI ≥ 30 kg/m²) for both female and male patients. Samples with no pre-morbid illnesses were defined as hypertensive (systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg), raised FBS (FBS 5.6–6.99 mmol/L), DM (FBS ≥ 7 mmol/L), low HDLC (< 1.29 mmol/L in females and HDLC < 1.03 mmol/L in males) and high TG (≥ 1.7 mmol/L for both genders).

Statistical analyses were performed using the Statistical Package for the Social Sciences version 11.5 (SPSS Inc, Chicago, IL, USA). Student's *t*-test was used to compare the means. Pearson's Chi-square test was used to identify the association between WC and BMI with metabolic risk factors and receiver operating characteristic (ROC) curve analysis. Youdens' index was used to identify the optimal cut-off points, sensitivity and specificity.

## RESULTS

Table I shows the demographic distribution of the study samples (n = 355) and Table II shows the associations of BMI

**Table III. Optimal cut-off points, AUC, sensitivities and specificities of BMI and WC associated with metabolic risk factors in females.**

| Risk factor | BMI cut-off | AUC | 95% CI | Sensitivity; Specificity | WC cut-off | AUC | 95% CI | Sensitivity; specificity |
|---|---|---|---|---|---|---|---|---|
| Low HDL | 22.9<br>30* | 0.666 | 0.579–0.752 | 93.7; 38.6<br>45.0; 72.9 | 85.5<br>88†<br>80§ | 0.727 | 0.674–0.807 | 84; 53<br>79; 56<br>92; 39 |
| High TG | 25.5<br>30* | 0.561<br>Asymptotic sig. | 0.477–0.645 | 77.1; 43.9<br>38.6; 62.2 | 92.5<br>88†<br>80§ | 0.603 | 0.521–0.686 | 65; 41<br>75; 58<br>81; 75 |
| Raised FBS | 23.7<br>30* | 0.637 | 0.553–0.721 | 92.9; 41.3<br>38.4; 70.7 | 84.5<br>88†<br>80§ | 0.647 | 0.563–0.731 | 85; 46<br>79; 50<br>91; 33 |
| Hypertension | 23.9<br>30* | 0.751 | 0.679–0.823 | 92.0; 45<br>46.0; 94 | 87<br>88†<br>80§ | 0.772 | 0.700–0.845 | 86; 60<br>83; 60<br>94; 41 |
| ≥ 2 risk factors | 23.7<br>30* | 0.740 | 0.657–0.823 | 93.0; 52<br>46.0; 83 | 84.5<br>88†<br>80§ | 0.779 | 0.699–0.858 | 88; 61<br>82; 64<br>95; 47 |

Note: Low HDL: < 1.29 mmol/L for females and < 1.03 mmol/L for males.
* BMI value of WHO criteria to define MS.(13) High TG: ≥ 1.7 mmol/L
† WC value of ATP111 NCEP criteria to define MS.(13) Raised FBS: ≥ 7 mmol/L
§ WC value of IDF (major criteria) to define MS.(13) Hypertension: ≥ 130 mmHg systolic BP or ≥ 85 mmHg diastolic BP
HDL: high-density lipoprotein; TG: triglycerides; FBS: fasting blood sugar; AUC: area under curve; CI: confidence interval; WC: waist circumference

**Table IV. Optimal cut-off points, areas under curve, sensitivities and specificities of BMI and WC associated with metabolic risk factors in males.**

| Risk factor | BMI cut-off | AUC | 95% CI | Sensitivity; Specificity | WC cut-off | AUC | 95% CI | Sensitivity; specificity |
|---|---|---|---|---|---|---|---|---|
| Low HDL | 23.1<br>30* | 0.468<br>Asymptotic Sig. | 0.381–0.558 | 68; 32<br>78; 84 | 78<br>102†<br>90§ | 0.470<br>Asymptotic Sig. | 0.382–0.558 | 91; 12<br>14; 79<br>45; 47 |
| High TG | 25.8<br>30* | 0.571<br>Asymptotic Sig. | 0.487–0.657 | 52; 63<br>78; 20 | 89<br>102†<br>90§ | 0.572<br>Asymptotic Sig. | 0.487–0.657 | 56; 55<br>13; 79<br>45; 47 |
| Raised FBS | 21<br>30* | 0.604 | 0.520–0.688 | 94; 25<br>20; 90 | 87<br>102†<br>90§ | 0.677 | 0.598–0.757 | 76; 52<br>27; 90<br>60; 62 |
| Hypertension | 25<br>30* | 0.701 | 0.623–0.778 | 66; 72<br>24; 92 | 91<br>102†<br>90§ | 0.735 | 0.662–0.808 | 64; 73<br>28; 89<br>67; 66 |
| ≥ 2 risks | 25.4<br>30* | 0.707 | 0.739–0.871 | 61; 73<br>20; 90 | 87.5<br>102†<br>90§ | 0.725 | 0.648–0.802 | 78; 61<br>26; 86<br>66; 68 |

Note: Low HDL: < 1.29 mmol/L for females and < 1.03 mmol/L for males.
* BMI value of WHO criteria to define MS.(13) High TG: ≥ 1.7 mmol/L
† WC value of ATP111 NCEP criteria to define MS.(13) Raised FBS: ≥ 7 mmol/L
§ WC value of IDF (major criteria) to define MS.(13) Hypertension: ≥ 130 mmHg systolic BP or ≥ 85 mmHg diastolic BP
HDL: high-density lipoprotein; TG: triglycerides; FBS: fasting blood sugar; AUC: area under curve; CI: confidence interval; WC: waist circumference

and WC with metabolic risk factors in female and male patients. In general, the male patients were older in age. The frequency of DM among female and male patients was virtually the same. Despite hypertension being more prevalent among females, their mean blood pressure levels were almost identical. With regard to biochemical parameters, low serum HDLC was more prevalent among females, while raised FBS and high TG were more prevalent in males. The mean HDLC in males was normal whereas that for females was lower. The means of FBS and TG were almost similar for both genders.

Tables III and IV show the optimal cut-off points, areas under the curve (AUC), sensitivities and specificities for BMI and WC of individual metabolic risk factors and ≥ 2 metabolic risk factors in females and males, respectively. In females, a WC of 84.5 cm was identified as the optimal cut-off point to predict ≥ 2 metabolic risk factors and raised FBS. However, the optimal cut-off point for low HDLC was 85.5 cm and that for hypertension and high TG was 87.0 cm and 92.5 cm, respectively, with corresponding sensitivities and specificities. A BMI of 23.7 kg/$m^2$ was identified as the optimal cut-off point to predict raised FBS and ≥ 2 metabolic risk factors, while BMI of 23.9 kg/$m^2$, 22.9 kg/$m^2$ and 25.5 kg/$m^2$ were identified for hypertension, low HDLC and high TG, respectively, with corresponding sensitivities and specificities. For male patients, an optimal WC of 87.5 cm was

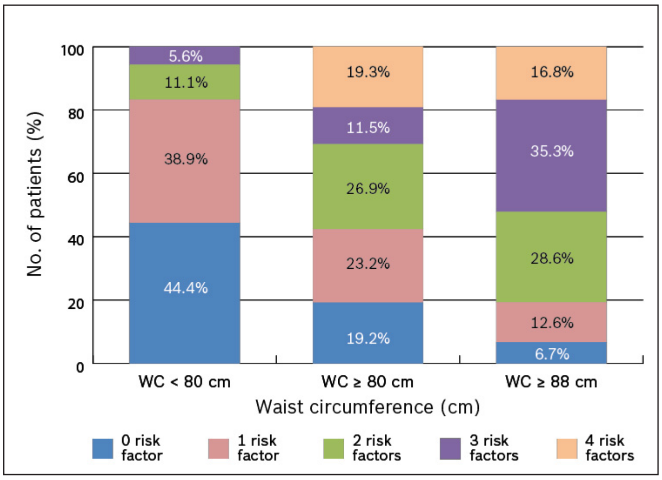


**Fig. 1** Graph shows the comparison of metabolic risk in females based on different waist circumference cut-off points.

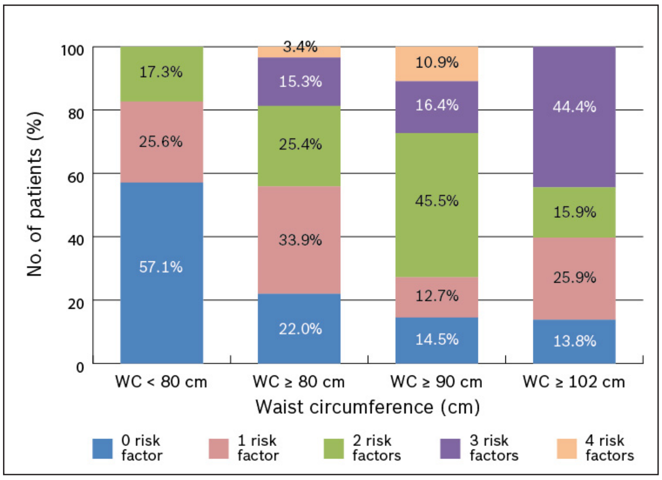


**Fig. 2** Graph shows the comparison of metabolic risk in males based on different waist circumference cut-off points.

identified as the cut-off point to predict ≥ 2 metabolic risk factors, and that for predicting hypertension was 91 cm, high TG 89 cm, raised FBS 87 cm and low HDLC 78 cm, with corresponding sensitivities and specificities. A BMI of 25.4 kg/m$^2$ was identified as the optimal cut-off point to predict ≥ 2 metabolic risk factors, 25 kg/m$^2$ for hypertension, 21 kg/m$^2$ for raised FBS, 25.8 kg/m$^2$ for high TG and 23.1 for low HDLC, with corresponding sensitivities and specificities.

In females, the optimal WC cut-off point of 84.5 cm identified in this study was more sensitive than that of 88.0 cm used by ATP111 NCEP to define MS. Similarly, for males, the WC of 87.5 cm identified in this study was more sensitive than the measurement of 90 cm and 102 cm used by IDF and ATP111 NCEP, respectively. Likewise, the optimal BMI cut-off point of 23.7 kg/m$^2$ in females and 25.5 kg/m$^2$ in males to predict ≥ 2 metabolic risk factors were more sensitive than the WHO criterion of 30 kg/m$^2$. There was a larger AUC exhibited by WC compared to BMI to predict ≥ 2 metabolic risk factors and most of the individual metabolic risk factors, thus indicating that WC was a better predictor of MS than BMI. Hypertension exhibited the largest AUC among the individual metabolic risk factors in both the WC and BMI ROC curves. Therefore, it was the most closely associated risk factor for developing MS (Tables III & IV).

The number of metabolic risk factors for MS was higher in female patients when a WC cut-off point ≥ 88 cm (ATP111 NCEP criteria) was applied compared to when WC ≥ 80 cm (IDF criteria) was used. Similarly, when the ATP111 NCEP and modified WHO criteria of WC ≥ 102 cm was applied to the male samples, the number of metabolic risk factors was found to be higher than when WC ≥ 90 cm (IDF criteria) was used. Both of these criteria yielded higher percentages of female and male patients with metabolic risk factors as compared to the criterion of WC < 80 cm (Figs. 1 & 2). Among the 355 subjects in our study, 19.7% had no risk factor, while 21.4% had one, 28.2% had two, 21.4% had three and 9.5% had four metabolic risk factors. The proportion of MS, as defined by the IDF, was 48.7% (31% in females and 17.7 % in males).

## DISCUSSION

The optimal WC cut-off points of 84.5–92.5 cm in females and 87.0–91.0 cm in males to predict individual metabolic risk factors in our study are consistent with the IDF definition of central obesity.[13] Similarly, the optimal BMI cut-off points of 23.7 kg/m$^2$ in women and 25.5 kg/m$^2$ in men are in agreement with the WHO Western Pacific Region revised guidelines 2000 for overweight and obesity[24,25] (Tables III and IV). Our findings also correspond to those of other studies conducted in Asian countries.[15,26-34] However, this study did not show any significant cut-off points to predict high TG in both genders and low HDLC in males. A BMI of 30 kg/m$^2$, as defined by the WHO criterion[13] was found to be less sensitive for predicting individual metabolic risk factors for MS in both genders in this study.

The optimal WC cut-off point of 84.5 cm to predict ≥ 2 metabolic risk factors in females is consistent with the IDF[13] criterion for MS, although it is lower than that used by the ATP111 NCEP[13] to define MS. Similarly, the optimal WC cut-off point of 87.5 cm in men is lower than that used by both IDF[13] and ATP111 NCEP.[13] The slightly larger WC in females and smaller WC in males could be due to the subjective nature of WC measurement, as it is difficult to remove all the layers of clothing in females and to locate the anterior superior iliac spine in men. Also, patients may not be following the breathing instructions properly. We tried to overcome these limitations by taking measurements at the mid-point between the lower costal cartilage and the anterior superior iliac spine, and by making the tape as tight as possible on expiration.

Although there is a 10-cm gap in the WC cut-off points between females and males by IDF and 14-cm gap by ATP111 NCEP criteria, a smaller gap (and even zero gap) has been reported in other studies. Misra et al[31] in India reported a 6-cm gap (males 78 cm, females 72 cm), while Hara et al[33] in Japan reported a 7-cm gap (males 85 cm, 78 cm females). Zero gap was reported by Zaher et al (83 cm) in Malaysia[15] and Wildman et al (80 cm) in China.[35] This is consistent with the observations of Misra et al[12] and Tan et al[36] that the WC used to define central obesity is not applicable uniformly to all populations and ethnic groups. This study included three ethnic groups with different lifestyles.

Compared to BMI, WC showed a stronger association with ≥ 2 metabolic risk factors, as shown by the higher AUC and OR values. This finding is consistent with those of Li et al and others.[1,29,37] The ORs for developing ≥ 2 metabolic risk factors in females with WC ≥ 80 cm and BMI ≥ 23 kg/m$^2$ were 19.7 (95% CI 7.57–51.3) and 15.3 (95% CI 5.49–42.9), respectively. The corresponding ORs for males with WC ≥ 80 cm and BMI ≥ 25 kg/m$^2$ were 7.53 (95% CI 3.79–14.9) and 2.39 (95% CI 1.29–4.42), respectively. Therefore, WC may prove to be a better predictor than BMI. Since the WC cut-off point for both females and males was ≥ 80 cm (Tables III and IV) and the percentage of patients with ≥ 2 metabolic risk factors increased significantly when WC ≥ 80 cm was used in both females and males (Figs. 1 & 2), we would have missed many cases of MS if a cut-off WC ≥ 88 cm in females and ≥ 102 cm in males were used to screen for MS.

WHO has acknowledged that WC is the easiest and most efficient anthropometric index for fatness and fat location.[38] Elevated WC is a well-accepted cause of insulin resistance, resulting in hypertension, dyslipidaemia, impaired fasting glucose and DM.[16-18] This may explain the higher prevalence of hypertension, lower HDLC and higher TG in females than males, and hence more females with MS (Table II). All cut-off points in this study were identified as the best balanced sensitivity and specificity values of BMI and WC using Youden's index. They can be used to identify individuals who should be targeted for early intervention to prevent the development of CHD. However, it must be acknowledged that cut-off points are arbitrary.[35] This notion is supported in our study by the fact that 11.1% of females and 17.9% of males had ≥ 2 metabolic risk factors even though their WC was < 80 cm. Based on IDF criteria, the proportion of MS in our sample was 48.7%. Higher frequencies of large WC, hypertension, low HDLC, high TG and raised FBS predisposed females to MS as compared to males (ratio 31.0:17.7).

This study has several limitations. First, we had the lowest participation by the youngest age group (13–18 years) due to difficulties in obtaining informed consent, anxiety regarding needles and refusal to fast. In addition, most of the patients enrolled were already on treatment for hypertension, DM and hypercholesterolaemia, which imposed some limitations on the study. We tried to overcome these by obtaining the necessary sample size and by using data documented before treatment. Finally, as this was a hospital-based, cross-sectional pilot study, the findings do not represent the whole Malaysian population or the local community. Further larger population-based studies are necessary to support our findings.

In conclusion, this study has identified WC (≥ 87.5 cm in males and ≥ 84.5 cm in females) as the most sensitive indicator to predict ≥ 2 metabolic risk factors for developing MS. Based on our study findings, we recommend that BMI calculation should be a routine practice in local medical clinics, and that females and males with BMI ≥ 23 kg/m$^2$ and ≥ 25 kg/m$^2$, respectively, be screened for MS. Additionally, metabolic risk factors should be screened when WC ≥ 80 cm is found in both genders, regardless of BMI. We also propose that obesity and MS be recognised as two of the causes of juvenile and adult hypertension. Due to the high incidence of MS, large population studies are necessary in order to introduce interventions to prevent cardiovascular disease and DM. Further studies should be conducted to identify the associations of BMI and WC with dyslipidaemia in males, as our finding differs from those of other studies.

## REFERENCES


1. Yusuf S, Hawken S, Ounpuu S, et al. Effect of potentially modifiable risk factors associated with myocardial infarction in 52 countries (the INTERHEART study): case-control study. Lancet 2004; 364:937-52.
2. Liberopoulos EN, Mikhalidis DP, Elisaf MS. Diagnosis and management of the metabolic syndrome in obesity. Obes Rev 2005; 6:283-96.
3. Klein S, Allison DB, Heymsfield SB, et al. Waist circumference and cardiometabolic risk: a consensus statement from Shaping America's Health: Association for Weight Management and Obesity Prevention; NAASO, The Obesity Society; the American Society for Nutrition; and the American Diabetes Association. Am J Clin Nutr 2007; 85:1197-202.
4. Institute for Public Health (IPH). The Third National Health and Morbidity Survey (NHMS 111) 2006; National Status. Ministry of Health, Malaysia 2008. Available at: psasir.upm.edu.my/6543/. Accessed August 23, 2010.
5. World Health Organization. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organ Tech Rep Ser 1995; 854:1-452.
6. Hsieh SD, Yoshinaga H, Muto T, Sakurai Y, Kosaka K. Health risks among Japanese men with moderate body mass index. Int J Obes Relat Metab Disord 2002; 24:358-62.
7. Wang J, Russell-Aulet M, Mazariegos M, et al. Body fat by dual photon absorptiometry (DPA): comparisons with traditional methods in Asians, Blacks and Caucasians. Am J Hum Biol 1992; 4:501-10.
8. Pouliot MC, Després JP, Lemieux S, et al. Waist circumference and abdominal sagittal diameter: best simple anthropometric indices of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. Am J Cardiol 1994; 73:460-8.
9. Kissebah AH, Vydelingum N, Murray R, et al. Relation of body fat d istribution to metabolic complications of obesity. J Clin Endocrinol Metab 1982; 54:254-60.
10. Wang Y, Rimm EB, Stampfer MJ, Willett WC, Hu FB. Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. Am J Clin Nutr 2005; 81:555-63.
11. Smith SR, Bai F, Charbonneau C, Janderová L, Argyropoulos G. A promoter genotype and oxidative stress potentially link resistin to human insulin resistance. Diabetes 2003; 52:1611-8.
12. Misra A, Wasir JS, Vikram NK. Waist circumference criteria for the diagnosis of abdominal obesity are not applicable uniformly to all populations and ethnic groups. Nutrition 2005; 21:969-76.
13. Tan BT, Kantilal HK, Singh R. Prevalence of metabolic syndrome among Malaysians using the International Diabetes Federation, National Cholesterol Education Program and Modified World Health Organisation Definitions. Mal J Nutr 2008; 14:65-77.
14. Zimmet P, Maglian D, Matsuzawa Y, Alberti G, Shaw J. The metabolic syndrome: a global public health problem and a new definition. J Atherosclera Thromb 2005; 12:259-300.
15. Zaher ZM, Zambari R, Pheng CS, et al. Optimal cut-off levels to define obesity: body mass index and waist circumference, and their relationship to cardiovascular disease, dyslipidaemia, hypertension and diabetes in Malaysia. Asia Pac J Clin Nutr 2009; 18:209-16.
16. Björntorp P. Body fat distribution, insulin resistance, and metabolic diseases. Nutrition 1997; 13:795-803.
17. Seppälä-Lindroos A, Vehkavaara S, Häkkinen AM, et al. Fat accumulation

in the liver is associated with defects in insulin suppression of glucose production and serum free fatty acids independent of obesity in normal men. J Clin Endocrinol Metab 2002; 87:3023-8.
18. Sinha R, Dufour S, Petersen KF, et al. Assessment of skeletal muscle triglyceride content by (1) H nuclear magnetic resonance spectroscopy in lean and obese adolescents: relationship to insulin sensitivity, total body fat, and central adiposity. Diabetes 2002; 51:1022-7.
19. Duman BS, Turkoglu C, Gunay D, et al. The interrelationship between insulin secretion and action in type 2 diabetes mellitus with different degrees of obesity: evidence supporting central obesity. Diabetes Nutr Metab 2003; 16:243-50.
20. Asensio C, Cettour-Rose P, Theander-Carrillo C, Rohner-Jeanrenaud F, Muzzin P. Changes in glycaemia by leptin administration or high-fat feeding in rodent models of obesity/type 2 diabetes suggest a link between resistin expression and control of glucose homeostasis. Endocrinology 2004; 145:2206-13.
21. Hirosumi J, Tuncman G, Chang L, et al. A central role for JNK in obesity and insulin resistance. Nature 2002; 420:333-6.
22. Rajala MW, Qi.Y, Patel HR, et al. Regulation of resistin expression and circulating levels in obesity, diabetes, and fasting. Diabetes 2004; 53:1671-9.
23. Silha JV, Krsek M, Skrha JV. Plasma resistin, adiponectin and leptin levels in lean and obese subjects: correlations with insulin resistance. Eur J Endocrinol 2003; 149:331-5.
24. The IDF Consensus Worldwide Definition of the Metabolic Syndrome. In: International Diabetes Federation (2006) [online]. Available at: www.idf.org/webdata/docs/IDF_Meta_def_final.pdf. Accessed February 1, 2010.
25. Ko TC, Chan J, Chan A, et al. Doubling over ten years of central obesity in Hong Kong Chinese working men. Chin Med J (Engl) 2007; 120:1151-4.
26. Pan WH, Flegal KM, Chang HY, et al. Body mass index and obesity-related metabolic disorders in Taiwanese and US whites and blacks: implications for definition of overweight and obesity for Asians. Am J Clin Nutr 2004; 79:31-9.
27. Ko GT, Chan JC, Cockram CS, Woo J. Prediction of hypertension, diabetes, dyslipidaemia or albuminuria using simple anthropometric indexes in Hongkong Chinese. Int J Obes Relat Metab Disord 1999; 23:1336-42.
28. Zhou BF, Cooperative Meta-Analysis Group of the Working Group on Obesity in China. Predictive values of the body mass index and waist circumference for the risk factors of certain related diseases in Chinese adults--study on optimal cut-off points of body mass index and waist circumference in Chinese adults. Biomed Environ Sci 2002; 15:83-96.
29. Li G, Chen X, Jang Y, et al. Obesity, coronary artery disease risk factors and diabetes in Chinese: an approach to the criteria of obesity in the Chinese population. Obes Rev 2002; 3:167-72.
30. Vikram NK, Pandey RM, Misra A, et al. Non-obese (body mass index < 25 kg/m$^2$) Asian Indians with normal waist circumference have high cardiovascular risk. Nutrition 2003; 19:503-9.
31. Misra A, Vikram NK, Gupta R. Waist circumference cutoff points and action levels for Asian Indians for identification of abdominal obesity. Int J Obes (Lond) 2006; 30:106-11.
32. Deurenberg-Yap M, Chew SK, Deurenberg P. Elevated body fat percentage and cardiovascular risks at a low body mass index levels among Singaporean Chinese, Malays and Indians. Obes Rev 2002; 3:209-15.
33. Hara K, Matsushita Y, Horikoshi M, et al. A proposal for the cutoff point of waist circumference for the diagnosis of metabolic syndrome in the Japanese population. Diabetes Care 2006; 29:1123-4.
34. Ito H, Nakasuga K, Ohshima A, et al. Detection of cardiovascular risk factors by indices of obesity obtained from anthropometry and dual-energy X-ray absorptiometry in Japanese individuals. Int J Obes Relat Metab Disord 2003; 27:232-7.
35. Wildman RP, Gu D, Reynolds K, Duan X, He J. Appropriate body mass index and waist circumference cutoffs for categorization of overweight and central obesity among Chinese adults. Am J Clin Nutr 2004; 80:1129-36.
36. Tan CE, Ma S, Wai D, Chew SK, Tai ES. Can we apply the National Cholesterol Education Program Adult Treatment Panel definition of the metabolic syndrome to Asians? Diabetes Care 2004; 27:1182-6.
37. Janssen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. Am J Clin Nutr 2004; 79:379-84.
38. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organ Tech Rep Ser 2000; 894:i-xii, 1-253.