ORIGINAL ARTICLE

FACTORS INFLUENCING ABDOMINAL OBESITY BY WAIST CIRCUMFERENCE AMONG NORMAL BMI POPULATION

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ABSTRACT

The population with normal body mass index (BMI) but with abdominal obesity are most of the time the 'neglected' population in terms of health interventions. The aim of this study is to study the prevalence of abdominal obesity and to explore the factors causing abdominal obesity by using waist circumference (WC) measurement. A cross sectional study was conducted among a group of respondents in Tanjung Karang, Selangor, Malaysia from January until June 2010, among those aged 18 years old and above, to explore the demographic (gender and ethnics), lifestyle factors (physical activity, carbohydrate intake and smoking status) and measurement of body weight, height and waist circumference. A total of 629 subjects with normal BMI were studied. The prevalence of abdominal obesity was 36.1% based on WC (40.0% males and 70.0% females). The predictor model revealed that being non-Malay (aOR = 2.1; 95% CI: 1.35-3.20) and being female (aOR = 3.6; 95% CI: 2.51-5.06) were the associated factors of having abdominal obesity in normal BMI population. In conclusion, females and non-Malay were factors that were found to be associated with abdominal obesity in normal BMI population. This is important in targeting this vulnerable population with risk factors that can develop non communicable diseases for early interventions.

***Key words**: Abdominal obesity, waist circumference, lifestyle factors, normal BMI population.*

INTRODUCTION

Non communicable diseases (NCDs) is the top cause of death worldwide, with cardiovascular diseases responsible for 48% of these deaths, cancers 21%, chronic respiratory diseases 12%, and diabetes 3%[1]. In 2008, more than nine million of all deaths attributed to NCDs occurred before the age of 60; 90% of these "premature" deaths occurred in low and middle-income countries[1].

Despite all of the efforts that have been undertaken since the 1990s in combating NCD such as National Strategic Plan, programmes and guidelines, the prevalence of NCD and NCD risk factors in Malaysia continues to rise at an alarming rate[2]. This affects Malaysia economically in terms of expenses spent for NCD itself (70% of all health clinic attendances are related to NCD[2]) and premature deaths caused by NCDs will also reduce the workforces that in turn will affect the economy indirectly.

Non communicable diseases especially cardiovascular disease has been associated with abdominal obesity[3-5]. It was shown that abdominal obesity is an important contributor to major causes of health risk factors such as high blood cholesterol, high fasting blood sugar and high blood pressure[5,6]. Abdominal obesity can be measured using various anthropometric measurements with the most widely used, easiest and recommended is waist circumference (WC)[7,9-12]. Other methods are waist-to-hip ratio (WHR)[4,13] and waist-to-height ratio (WhtR)[8,14]. Among the factors associated with abdominal obesity identified are age[3,15], gender[9,16,17], ethnic[18,19] educational status[3,20], marital status[3,15], physical activities[8] and family history of obesity[3,20] .

Having normal BMI does not necessarily make a person free from the risk of developing NCDs since the main risk factor is abdominal obesity. According to the WHO guidelines, those with high BMI are recommended to reduce it by adopting healthy lifestyle, this has more or less resulted in those with normal or low BMI to pay little attention to it[8].

It is important to make sure that those that perceive they are healthy when their BMI is low or normal to pay more attention to the real risk of developing NCDs, which is having abdominal obesity. Population with normal BMI but with abdominal obesity is also a population which lack attentions are given to them in terms of awareness and interventions by healthcare providers. This population should be given priority as well since early interventions to prevent abdominal obesity will cut down the risk of developing NCDs hence reducing the NCD burden in this country.

This study will hopefully explore this poorly explored area of studying population with normal

BMI that lack attention in terms of interventions by healthcare providers even though they are silently having risk to develop NCDs due to abdominal obesity. This research is designed to answer the question on what are the factors associated with high waist circumference in normal body mass index persons among normal BMI population.

MATERIALS AND METHODS

Study design
A cross sectional study was done from January to June 2010, within the district of Kuala Selangor, Selangor.

Sampling
Using multistage random sampling, Kuala Selangor district and Tanjung Karang territory was selected. From the list of 14 traditional villages and housing estates in the territory that was acquired by using the list obtained from the Kuala Selangor Municipal Office (MDKS) and the District Health Office, simple random sampling was done to select seven villages. Cluster sampling was then done where all residents who consented to the study and aged 18 years and above were selected. The exclusion criteria is those who were bed ridden and not at home at the time of the study. A total of 1526 subjects were obtained from the final cluster sampling and out of these subjects, after anthropometric measurement was taken, 629 were among the normal BMI populations.

Each participant was informed and explained thoroughly regarding objectives of the study and written consent was obtained from participants during home visit. A standardized assisted and guided survey form was prepared and distributed to participants. The survey form was divided into demographic section, lifestyle factors and questions on cardiovascular risk section as well as anthropometric measurements section.

Data collection

Demographic data
Data on demographic information that was studied were gender and ethnic.

Lifestyle factors
For exercise variable, the subjects were asked about their exercise habit and were then categorized into active if they reported as exercising at least 150 minutes per week[21] and non-active if they don't exercise according to recommended duration. Smoking status were categorized into none smoker, smoker (no matter how many cigarettes per day) and ex-smoker (stopped smoking for 6 months and more[22]). For carbohydrate intake, subjects will self-report the frequency of their carbohydrate intake and are classified into frequent and non-frequent.

Physical examination
Weight and heights were measured without shoes and with light clothing, and body mass index was calculated as body weight (kg) divided by the square of height (m^2). Body mass index (BMI) was defined according to World Health Organization 2004[23] and categorized into Underweight (< 18.50 kg/m2), Normal (18.50–24.99 kg/m2), Overweight (25.0 – 29.99 kg/m2) and Obese (≥ 30.00 kg/m2).

Waist circumference (WC) was measured as the diameter at the level of the midpoint between the iliac crest and the lower border of the tenth rib in cm[24]. The cut off point for waist circumference for male is 90 (WC of ≥ 90 cm is considered as high and < 90 cm is low) while for female is 80 cm (WC of ≥ 80 cm is considered at high and < 80 cm is low[7]). Hip circumference was measured around the widest portion of the buttocks[24]. Waist-to-hip ratio was calculated by dividing WC with hip circumference in cm and categorized by gender; female: Low if ratio < 0.802, medium 0.802 to < 0.869 and high if ≥ 0.869. For male: low < 0.859, medium 0.859 to < 0.913 and high if ≥ 0.913[13].

Waist height ratio was calculated using formula of WC divided by height in cm. It is categorized as low (<0.5) and high (≥ 0.5) for both men and women[3].

Statistical analysis
All analyses were conducted by using SPSS Version 17.0. Data were expressed as percentages and association between groups were analyzed using Chi square test and Pearson Correlation. Multiple logistic regression was used to estimate the predictor of having high WC among the socio demographic and lifestyle categories. P value of <0.05 was taken as significant and OR with 95% confidence interval was used. The dependent variable was waist circumference and the independent variables were gender, ethnic, physical activity, carbohydrate intake and smoking status.

RESULTS

General population (n = 1526)
Among the general population of the sample, 82.2% was Malay, 15.8% Indian and Chinese make

up only 2.0%. The mean BMI for the population was 25.5 ± 5.58 kg/m^2 with female has higher BMI (26.1 ± 5.83 kg/m2) compared to male (24.7 ± 5.13 kg/m^2). The waist circumference was also higher among female (87.2 ± 16.22 cm versus 86.9 ± 14.50 cm). There was a strong (r=0.7) and significant (p<0.001) correlation between BMI and WC as shown in Figure 1.

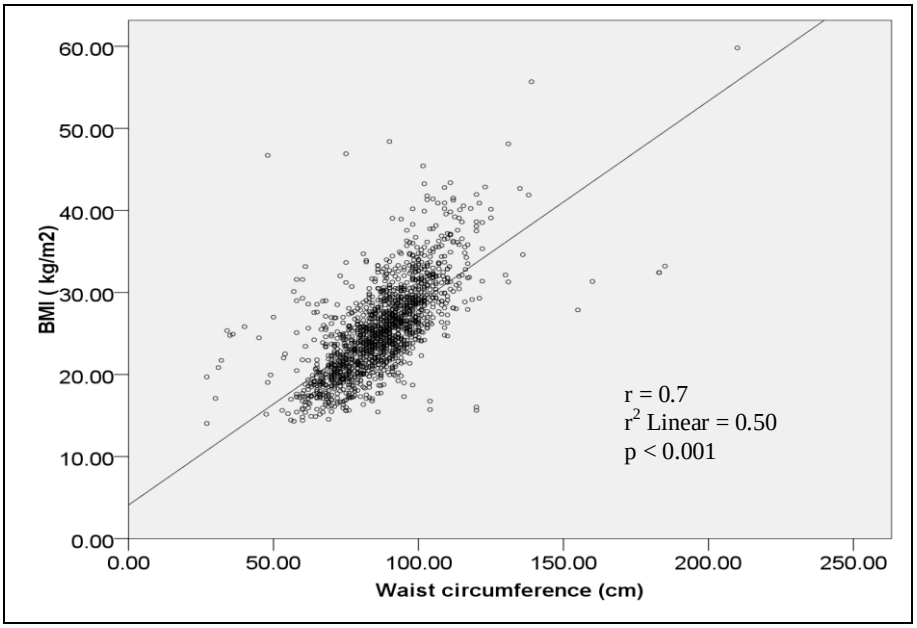
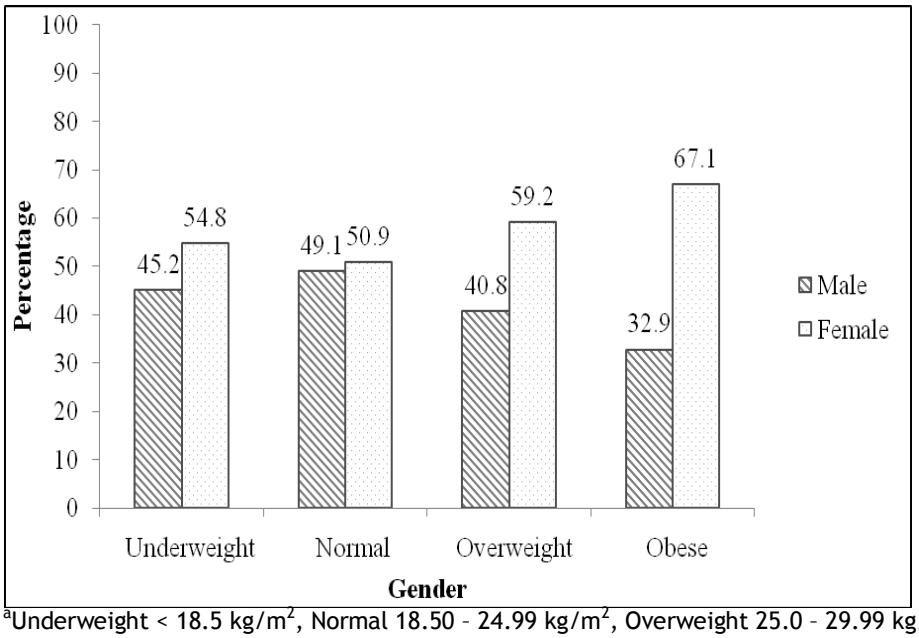


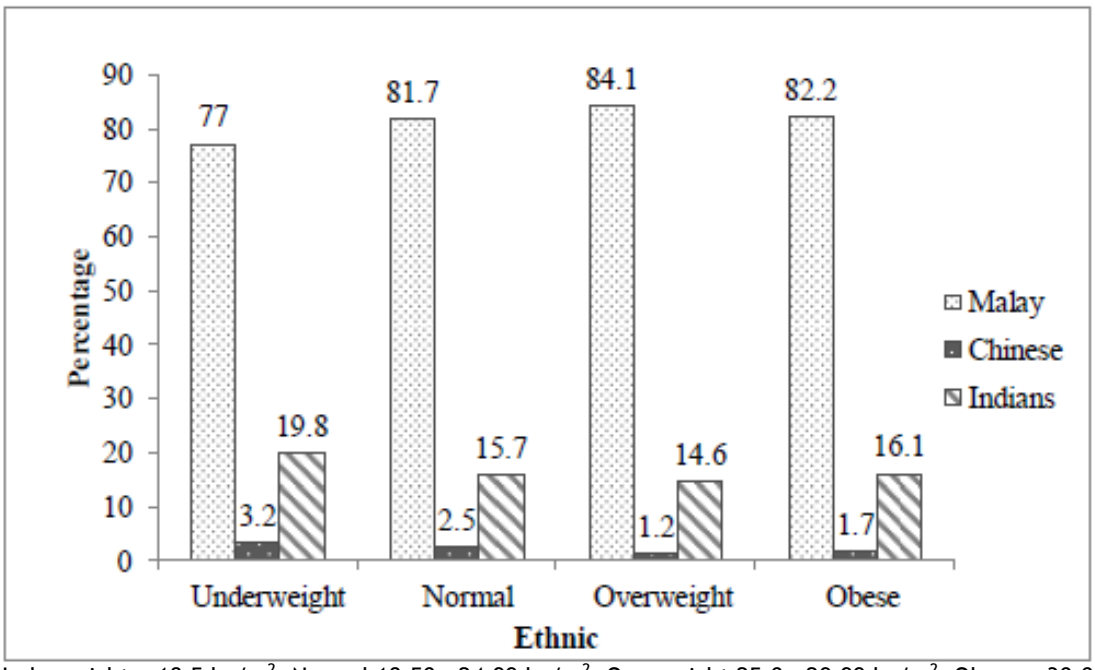
Figure 1. Correlation between WC and BMI

There were higher percentage of overweight and obesity in females (59.2%, 67.1%) compared to males (40.8%, 32.9%)(Figure 2). In view of ethnicity, Malays had the highest percentage of all BMI categories with the prevalence of overweight and obesity (51.3%) compared to among Indians (48.5%) and among Chinese (35.5%)(Figure 3).



[a]Underweight < 18.5 kg/m^2, Normal 18.50 – 24.99 kg/m^2, Overweight 25.0 – 29.99 kg/m^2, Obese ≥ 30.00 kg/m^2.

Figure 2. BMI[a] percentage according to Gender



[a]Underweight < 18.5 kg/m^2, Normal 18.50 – 24.99 kg/m^2, Overweight 25.0 – 29.99 kg/m^2, Obese ≥ 30.00 kg/m^2.

Figure 3. BMI[a] percentage according to Ethnic

As shown in Table 1, the percentage of high WC and WhtR was higher among female however not in WHR. Malays had the highest percentage of high WC, WHR and WhtR but when looking at within the ethnic, Indians had higher prevalence of high WC (66.0%) compared to Malays (58.2%) and Chinese (51.6%), higher WhtR (76.3%) compared to the other two ethnics (Malays 69.9%, Chinese 58.1%) but when it comes to WHR, Malays had slightly higher prevalence of WHR (56.9%) compared to Indians (56.8%) and Chinese (51.6%).

Table 1. Demographic characteristic of populations according to waist circumference, waist-hip-ratio and waist-height-ratio

	Gender		Ethnic		
n = 1526	**Male (*n* = 658)**	**Female (*n* = 868)**	**Malay (*n* = 1254)**	**Chinese (*n* = 31)**	**Indian (*n* = 241)**
	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**
Waist Circumference[a]					
Mean (sd)	86.89±14.50	87.19±16.22	86.87±18.92	85.19±11.92	88.33±13.54
Low	364 (58.6)	257 (41.4)	524 (84.4)	15 (2.4)	82 (13.2)
High	294 (32.5)	611 (67.5)	730 (80.7)	16 (1.8)	159 (17.6)
Waist Hip Ratio[b]					
Mean (sd)	0.91±0.12	0.88±0.13	0.89±0.13	0.88±0.09	0.89±0.12
Low	77 (27.4)	204 (72.6)	228 (81.1)	6 (2.1)	47 (16.7)
Medium	135 (35.7)	243 (64.3)	312 (82.5)	9 (2.4)	57 (15.1)
High	446 (51.4)	421 (48.6)	714 (82.4)	16 (1.8)	137 (15.8)
Waist Height ratio[c]					
Mean (sd)	0.53±0.09	0.57±0.11	0.55±0.11	0.53±0.09	0.56±0.09
Low	233 (52.1)	214 (47.9)	377 (84.3)	13 (2.9)	57 (12.8)
High	425 (39.4)	654 (60.6)	877 (81.3)	18 (1.7)	184 (17.1)

[a]Male: High - ≥ 90 cm, Low - < 90, Female: High - ≥ 80 cm, Low - < 80 cm, [b]Male: Low - < 0.859, medium- 0.859 to < 0.913, high - ≥ 0.91, Female: Low - < 0.802, medium 0.802 to < 0.869, high - ≥ 0.869, [c]Low - <0.5, High- ≥ 0.5.

Subgroup analysis among normal BMI population (n = 629)

The mean BMI was 22.1±1.88 kg/m^2 with female of 22.1±1.86kg/m^2 and male 22.0±1.90 kg/m^2. The mean WC for females was 79.2±9.96 cm, which was lower compared to male (81.2±10.44 cm). Among ethnics, Indian had the highest WC (83.4 ± 8.91) compared to Chinese (79.7±9.31 cm) and Malays (79.5±10.40 cm) as shown in Table 2.

Table2. Demographic characteristic of normal BMI populations according to waist circumference, waist-hip-ratio and waist-height-ratio

n = 629	Gender		Ethnic		
	Male (*n* = 309)	Female (*n* = 320)	Malay (*n* = 514)	Chinese (*n* = 16)	Indian (*n* = 99)
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Waist Circumference[a]					
Mean (sd)	81.19±10.44	79.16±9.96	79.54±10.40	79.71±9.31	83.42±8.91
Low	241 (60.0)	161 (40.0)	344 (85.6)	11 (2.7)	47 (11.7)
High	68 (30.0)	159 (70.0)	170 (74.9)	5 (2.2)	52 (22.9)
Waist Hip Ratio[b]					
Mean (sd)	0.89±0.10	0.86±0.10	0.88±0.11	0.87±0.09	0.89±0.08
Low	42 (29.6)	100 (70.4)	117 (82.4)	4 (2.8)	21 (14.8)
Medium	78 (49.1)	81 (50.9)	137 (86.2)	2 (1.3)	20 (12.6)
High	189 (57.6)	139 (42.4)	260 (79.3)	10 (3.0)	58 (17.7)
Waist Height ratio[c]					
Mean (sd)	0.49±0.06	0.52±0.07	0.50±0.07	0.49±0.05	0.52±0.05
Low	154 (53.8)	132 (46.2)	245 (85.7)	9 (3.1)	32 (11.2)
High	155 (45.2)	188 (54.8)	269 (78.4)	7 (2.0)	67 (19.5)

[a]Male: High - ≥ 90 cm, Low - < 90, Female : High - ≥ 80 cm, Low - < 80 cm, [b]Male: Low - < 0.859, medium- 0.859 to < 0.913, high - ≥ 0.91, Female: Low - < 0.802, medium 0.802 to < 0.869, high - ≥ 0.869, [c]Low - <0.5, High- ≥ 0.5.

There were higher prevalence of hypertension (32.2%), diabetes mellitus (14.1%) and coronary heart diseases (4.4%) among those with high WC compared to low value (Table 3). The prevalence of high WC (abdominal obesity) is 36.1% (Table 4). Gender, ethnic and smoking were noted to have significant associations with high WC (p = < 0.001, p = 0.001, p = 0.001).

Table 3. Prevalence of self reported diseases according to WC in normal BMI population

n = 629	Hypertension		Diabetes Mellitus		Coronary Heart Disease	
	n (%)		n (%)		n (%)	
WC	Yes	No	Yes	No	Yes	No
High	73 (32.2)	154 (67.8)	32 (14.1)	195 (85.9)	10 (4.4)	217 (95.6)
Low	52 (12.9)	350 (87.1)	22 (5.5)	380 (94.5)	11 (2.7)	391 (97.3)
(x^2, p value)	(33.67, <0.001*)		(13.75, <0.001*)		(1.26, 0.263*)	

* Pearson's Chi Square.

Table 4. Demographic characteristics of subjects and lifestyle factors among normal BMI population according to WC

n = 629		Waist Circumference (WC) Low (*n* = 402) *n* (%)	High (*n* = 227) *n* (%)	x^2	p value
Demographic					
	Gender			52.22	< 0.001*
	Male	241 (78.0)	68 (22.0)		
	Female	161 (50.3)	159 (49.7)		
	Ethnic			11.08	0.001*
	Malay	344 (66.9)	170 (33.1)		
	Non-Malay	58 (50.4)	57 (49.6)		
Lifestyle					
	Physical activity			1.08	0.299
	Active	268 (65.4)	142 (34.6)		
	Non active	134 (61.2)	85 (38.8)		
	Carbohidrat intake			0.68	0.409
	Non frequent	235 (65.3)	125 (34.7)		
	Frequent	167 (62.1)	102 (37.9)		
	Smoking Status			14.64	0.001*
	Smoker	126 (75.4)	41 (24.6)		
	Ex-smoker	42 (66.7)	21 (33.3)		
	Non smoker	234 (58.6)	165 (41.4)		

*Pearson chi square.

As shown in Table 5, being female (Crude OR [cOR]) : 3.5 ; 95 % CI: 2.47,4.95), Non Malay (cOR : 1.9 ; 95% CI: 1.32 – 2.99) and non-smoker (cOR : 2.2 ; 95% CI: 1.45,3.25) had higher risk of having high WC. However, the predictor factor towards high WC were only women (Adjusted OR [aOR] : 3.6 ; 95% CI : 2.51,5.06) and Non Malay (aOR : 2.1 ; 95% CI : 1.35,3.20)(Table 6).

Table 5. Crude odd ratio of demographic and lifestyle risk factors on having high WC

Risk factor	Simple Logistics Regression		
	Crude OR*	P value	95 % CI
Gender			
Male	1		
Female	3.5	< 0.001	2.47 - 4.95
Ethnics			
Malay	1		
Non Malay	1.9	0.001	1.32 - 2.99
Physical Activity			
Non active	1		
Active	1.2	0.299	0.80 - 1.68
Carbohydrate intake			
Non frequent	1		
Frequent	1.1	0.409	0.83 - 1.59
Smoking status			
Smoker	1		
Ex-smoker	1.5	0.182	0.82 - 2.89
Non smoker	2.2	<0.001	1.45 - 3.25

* Crude OR is equivalent to estimated OR.

Table 6. Predictor factor towards high WC in normal BMI population

Risk factor	Multiple Logistic Regression		
	Adjusted OR	P value	95% CI
Ethnics			
Malay	1		
Non- Malay	2.1	0.001	1.35 - 3.20
Gender			
Male	1		
Female	3.6	< 0.001	2.51 - 5.06

DISCUSSION

From 1996 to 2006, Malaysia saw a dramatic increase in the prevalence of behaviour-linked diseases, including a 43% increase in hypertension, 88% increase in diabetes and 250% increase in obesity[2]. In 3rd National Morbidity Health Survey (NHMS) 2006, it was noted that overall prevalence of abdominal obesity was 17.4% with women's prevalence (26.0%) to be higher than men (7.2%)[25]. Looking at the major ethnics, Indians had the highest prevalence of abdominal obesity (28.2%), followed by Malays (18.6%) and Chinese (14.1%)[25].

The overall overweight and obesity rates for this studied population was slightly higher, that was 50.5% compared to the overweight and obesity rate noted during the NHMS III (43.1 %)[2]. This is

probably because this study was done in 2011, five years after the NMHS III and this can represent the increasing trend of overweight and obesity among Malaysian populations.

For obesity, this study found the same findings as NHMS III that is females had higher rate of obesity (22.1 %, NHMS III- 17.4 %) than males (14.3%, NHMS III – 10.0%) and comparable with studies done by Tan et al[18] when it comes to the gender findings. Malays and Indians also found to have more prevalence of obesity compared to other groups, the same results as the survey as well as other studies[18,19].

Prevalence of high WC was found to be higher among women and also within Indian ethnics, which is comparable with studies done in 63 other countries[26] and also another study done in Malaysia in 2008[27]. It was noted in the study that patterns of adiposity not only contributed to these geographic variations, but also genetic, environmental, and behavioural characteristics. The variety of WC in ethnicity is probably because the proportion of body tissues may vary at the same level of waist circumference for different ethnics[28].

In the current study, we detected that there were higher prevalence of abdominal obesity among normal BMI with rate of 36.1% which is almost the same rate found by a study in Japan[8]. This study also comparable with study done in Poland where it was found that female had 69.9%[15] abdominal obesity rate and this study showed rate of 70.0%. Abdominal obesity was also found to be higher in females compared to males and comparable with a few other studies[16,25].

When it comes to diseases that are associated with abdominal obesity, we have found that there are higher prevalence of self-reported NCDs (Hypertension, Diabetes Mellitus and coronary heart disease among those with higher WC. Obesity particularly abdominal obesity was associated with various cardiovascular risk factors[5]. Diabetes mellitus and cardiovascular risk factors were both associated with high WC[28].

Habitual smokers experienced a loss in waist circumference whereas those who quit smoking gained waist circumference[30]. However a lot of studies are associated with larger WC and WHR among smokers than ex-smokers and non-smokers[30]. In our study, it was found that those who are non-smoker are more likely to have abdominal obesity (cOR = 2.2; 95 % CI: 1.45-3.25) compared to ex-smoker (cOR 1.5; 95% CI: 0.82-2.89) and smoker. The reason why smokers are less likely to have abdominal obesity is because smoking increases energy expenditure, suppresses appetite and those who smokes are more likely to contract chronic diseases that will cause weight loss[15].

In our study, we also found that those who are frequently taking carbohydrate diet are more likely to have abdominal obesity (p = 0.409), comparable with studies done in Korea[31]. This is probably because obesity, which is induced by high carbohydrate diet is related to hyperinsulinemia, which may reduce fat oxidation and increase carbohydrate oxidation, leading to increased fat storage[31].

Some studies showed that where it was found that those with sufficient activities are less likely to develop abdominal obesity[16,20], contrary to the current study. Those who active were noted to be more likely to develop abdominal obesity (cOR 1.2; 95% CI: 0.80,1.68) compared to those who are inactive, the same findings found by Onat et al[32]. This is probably due to the nature of this cross sectional study whereby pre-existed sedentary lifestyle may determine the anthropometric characteristics that were found in this study[33].

In the predictor model, only ethnic and gender were found to be associated with abdominal obesity. The non-Malays were found to be 2.1 times at higher risk of getting high WC, and this probably contributed by the Indians, since it was found that 17.6% of them had high WC compared to Chinese (1.8%). The same finding about ethnic and gender being the factor for abdominal obesity was found in the study done in Malaysia by Kee et al.[25] and study in India found that high prevalence of abdominal obesity among normal BMI Indians[34]. This probably can be explained by study that showed that even in normal BMI populations, Indians has more tendencies to have insulin resistant[35]. Furthermore, we cannot exclude the influence of other factors that was not studied such as socio-economic and socio-cultural factors.

Females were 3.6 times at higher risk of getting high WC, and this is comparable with other studies[16,25,27]. This probably can be explained by studies about the differences of fat distribution in males and females where female was found to have larger abdominal subcutaneous adipose tissue area[36,37].

Despite all the findings, there were some limitations of this study in which the nature of the cross sectional data and the usage of self-reported survey such as information on carbohydrate intake, exercise and smoking habit

that may have been resulting in under reporting or over reporting of the lifestyle factors by the respondents. The measurement bias can also be caused while taking anthropometric measurements.

CONCLUSION

In conclusion, based on the findings in this study, it is suggested that all patients or clients of health clinics to be screened for abdominal obesity regardless of their BMI measurement especially among females and non-Malays namely Indians. This is actually to identify these populations with high risk of getting NCDs even with normal BMI so that early interventions or health education can be given even before they contract any NCDs. It is suggested that the research to be extended to other factors causing abdominal obesity especially in normal BMI population such as socio-cultural and also genetic studies using quantitative data.

ACKNOWLEDGEMENT

The author would like to gratefully acknowledge the Head of Department, Department of Community Health, National University Medical Centre, Malaysia and those who directly or indirectly involved in this study.

REFERENCES

1. WHO. News Release, Country profiles on non communicable disease trends in 193 countries, 14 September 2011. Available from: http://www.who.int/mediacentre/news/releases/2011/NCDs_profiles_20110914/en/index.html (accessed 24 April 2012).

2. Kementerian Kesihatan Malaysia. Kesihatan tanggungjawab kita bersama : seruan Menteri Kesihatan Malaysia. National Strategic Plan For Non Communicable Diseases, 2011.

3. Sahin H, Cicek B, Yılmaz M et al. Obesity prevalence, waist-to-height ratio and associated factors in adult Turkish males. *Obes Res Clin Prac* 2011; **5:** 29-35.

4. Dhaliwal SS, Welborn TA. Central obesity and cigarette smoking are key determinants of cardiovascular disease deaths in Australia: A public health perspective. *Prev Med* 2009; **49**: 153–7.

5. Ascaso JF, Romero P, Real JT, Lorente RI, Mart´ınez-Valls J, Carmen R. Abdominal obesity, insulin resistance, and metabolic syndrome in a Southern European population. Eur J Intern Med 2003; **14**: 101–6.

6. Lawlor DA, Benfield L, Logue J et al. Association between general and central adiposity in childhood, and change in these, with cardiovascular risk factors in adolescence: prospective cohort study. *BMJ* 2010; **341**: c6224.

7. International Diabetes Federation. The IDF consensus worldwide definition of the metabolic syndrome. 2006. Available from: www.idf.org|VAT BE433.674.528 (accessed 17 May 2012).

8. Hsieh SD, Yoshinaga H, Muto T. Waist-to-height ratio, a simple and practical index for assessing central fat distribution and metabolic risk in Japanese men and women. *Int J Obesity* 2003; **27**: 610–6.

9. Narksawat K, Podang J, Punyarathabundu P, Podhipak A. Waist circumference, body mass index and health risk factors among middle aged Thais. *Asia-Pac J Public Health* 2007; **19**(3): 10–15.

10. Pouliot M, Després J, Lemieux S. Waist circumference and abdominal sagittal diameter: best simple anthropometric indexes of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. *Am J Cardiol*.1994; **73**(7): 460–8.

11. Moy FM, Atiya AS. Waist circumference as a screening tool for weight management evaluation using Receiver Operating Characteristic Curves for Malay subjects. *Asia-Pac J Public Health* 2003; **15**: 99-104.

12. Kurpad SS, Tandon H, Srinivasan K. Waist circumference correlates better with body mass index than waist-to-hip ratio in Asian Indians. *Natl Med J India* 2003; **16**(4): 189-92.

13. Jee SH, Lee S Y, Nam CM, Kim SY, Kim MT. Effect of smoking on the paradox of high waist-to-hip ratio and low body mass index. *Obes Res* 2002; **10**(9): 891-95.

14. Ahmet SC. Body mass index, waist-to-height ratio, cardiometabolic risk factors and diseases in a new obesity classification proposal. *The Open Obesity Journal* 2011; **3**: 56-61.

15. Skrzypczaka M, Szweda A, Pawlinka-Chmara R, Skrzypulec V. Body mass index, waist to hip ratio and waist/height in adult polish women in relation to their education, place of residence, smoking and alcohol consumption. *Journal of Comparative Human Biology* 2008; **59**: 329-42.

16. Arambepola C, Ekanayake R, Fernando D. Gender differentials of abdominal obesity among the adults in the district of Colombo, Sri Lanka. *Prev Med* 2007; **44**: 129–34.

17. Yoo S, Cho HJ, Khang YH. General and abdominal obesity in South Korea, 1998–2007: Gender and socioeconomic differences. *Prev Med* 2010; **5**: 460–5.

18. Tan AKG, Dunn RA, Abdul Samad MI, Mustapha FI. Sociodemographic and health-lifestyle determinants of obesity risks in Malaysia. *AsiaPac J Public Health* 2011; **23**(2): 192-02.

19. Rodriguez R, Mowrer J, Romo J, Aleman A, Weffer SE, Ortiz RM. Ethnic and gender disparities in adolescent obesity and elevated systolic blood pressure in a rural us population. *Clin Pediatr* 2010; **49**(9): 876-84.

20. Hajian-Tilaki KO, Heidari B. Association of educational level with risk of obesity and abdominal obesity in Iranian adults. *J Public Health* 2009; **32**(2): 202-9.

21. WHO. Global recommendations on physical activity for health. World Health Organizations, 2010. Available from http://whqlibdoc.who.int/publications/2010/9789241599979_eng.pdf (accessed 15 April 2012).

22. Ghani WMN, Razak IA, Yang YH et al. Factors affecting commencement and cessation of smoking behaviour in Malaysian adults. *BMC Public Health* 2012; **12**: 207. Available from: http://www. Biomedcentral .com/1471-2458/12/207 (accessed on 24 May 2012).

23. WHO. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* 2004; **363**: 157-63.

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

25. Kee CC, Jamaiyah H, Noor Safiza MN et al. Abdominal obesity in Malaysian adults: National Health and Morbidity Survey III (NHMS III, 2006) Mal J Nutr.2008; **14**(2): 125-35.

26. Balkau B, Deanfield JE, Després JP et al. International day for the evaluation of abdominal obesity (idea) a study of waist circumference, cardiovascular disease, and diabetes mellitus in 168 000 primary care patients in 63 countries. *Circulation* 2007; **116**: 1942-51.

27. W Nazaimoon WM, Aziz I, Amir S et al. Prevalence of metabolic syndrome and its risk factors in adult Malaysians: Results of a nationwide survey. *Diabetes Res Clin Pr* 2011; **91**: 239-45.

28. 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.

29. Koh-Banerjee P, Chu N F, Spiegelman D et al. Prospective study of the association of changes in dietary intake, physical activity, alcohol consumption, and smoking with 9-y gain in waist circumference among 16 587 US men. *Am J Clin Nutr* 2003; **78**: 719–27.

30. Pasupathy P, Bakthavanthsalam G, Rao YY, Farook J. Cigarette smoking-effect of metabolic health risk: a review. *Diabetes and Metabolic Syndrome: Clinical Research & Reviews* 2009; **3**: 120-7.

31. Youn S, Woo HD, Cho YA, Shin A, Chang N , Kim J. Association between dietary carbohydrate, glycemic index, glycemic load, and the prevalence of obesity in Korean men and women. *Nutr Res* 2012; **32**: 153–9.

32. Onat A, Uyarel H, Hergenc G, Karabulut A, Albayrak S, Can G. Determinants and definition of abdominal obesity as related to risk of diabetes, metabolic syndrome and coronary disease in Turkish men: A prospective cohort study. *Atherosclerosis* 2007; **191**: 182–90.

33. Chen Y, Mao Y. Obesity and leisure time physical activity among Canadians. *Prev Med* 2006; **42**: 261–5.

34. Vikram NK, Pandey RM, Misra A, Sharma R, Devi JR, Khanna N. Non-obese (body mass index < 25 kg/m2) Asian Indians with normal waist circumference has high cardiovascular risk. *Nutrition* 2003; **19**: 503–9.

35. Palaniappan LP, Kwan AC, Abbasi F, Lamendola C, McLaughlin TL, Reaven GM. Lipoprotein abnormalities are associated with insulin resistance in South Asian Indian women. *Metabolism* 2007; **56:** 899-904.

36. He H, Ni Y, Chen J et al. Sex difference in cardiometabolic risk profile and adiponectin expression in subjects with visceral fat obesity. *Transl Res* 2010; **155**(2): 71-7.

37. Lemieux S, Prud'homme D, Bouchard C, Tremblay A, Despes J. Sex differences in the relation of visceral adipose tissue accumulation to total body fatness. *Am J Clin Nutr* 1993; **58**: 463-7.