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An Interrelationship between Blood Pressure, Body Roundness Index, Waist Circumference, and Waist to Height Ratio

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An Interrelationship between Blood Pressure, Body Roundness Index, Waist Circumference, and Waist to Height Ratio

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Abstract
Obesity is a global epidemic. Obesity related comorbidities include hypertension, diabetes, dyslipidemia, obstructive sleep apnea, and sudden death. Abdominal adiposity has been blamed for causing cardiovascular complications. The body roundness index (BRI) has been considered to be a superior anthropometric measure for abdominal adiposity. The aim of the study was to find the relationship of blood pressure in healthy individuals to BRI, waist circumference (WC), and waist to height Ratio (WHtR). It also tried to find out the relation of BRI to WC and WHtR. This cross-sectional study was conducted on 300 individuals aged between 18 and 60 years who were apparently healthy (not on any treatment or physical training) and willing to participate in this study. A structured questionnaire was used to collect the data. Parameters like height, weight, and WC were measured. BRI and WHtR were calculated. The data was analyzed using descriptive and inferential statistics. We observed that BRI was well correlated to the WC, body mass index (BMI), and WHtR. Both the systolic and diastolic blood pressure correlated well with BRI. BRI and WHtR, both are good parameters to evaluate the blood pressure of an individual.

Keywords: Body roundness index; Blood pressure; Body mass index.

1. INTRODUCTION

In recent years, overweight and obesity have been recognized to be worldwide health problems. The National Center for Health Statistics data shows that a third of US adults of 20 years of age or above are obese [1]. The National Health Morbidity Survey in Malaysia revealed that among adults, 20.7% were overweight and 5.8% obese (0.3% of whom had body mass index (BMI) values of >40.0 kg/m^2) [2]. Obesity can lead to hypertension, diabetes, dyslipidemia, obstructive sleep apnea, and sudden death [3]. This has led to a renewed interest in the field of anthropometry. The BMI, introduced in the 19th century by Quetelet, is the commonest index used to assess obesity status. In recent literature, BMI has been criticized for not providing information on body fat distribution. It may not be helpful to differentiate a muscular individual from an obese one [4]. Abdominal adiposity has been associated with high cardiovascular risk, and BMI fails to describe it. It therefore necessitated additional anthropometric indices to assess abdominal adiposity. The World Health Organization guidelines stated that waist circumference (WC) and waist to height ratio (WHtR) as more useful anthropometric indices than BMI as an indicator of obesity [5]. Recently Thomas *et al.* developed an index called Body Roundness Index (BRI) which was considered to be well correlated with visceral adiposity [6]. This study was therefore conducted on 300 apparently healthy adults to evaluate the relationship of BRI, WC, and WHtR to blood pressure (BP) as well as correlate BRI with WC and WHtR.

2. METHOD(S)

This cross-sectional study was conducted on 300 individuals aged between 18 and 60 years who were apparently healthy and willing to participate. They were not on any treatment or physical training. By using the formula for a single population, the sample size was calculated. A convenient sampling method was used to collect the data. Individuals suffering from hypothyroidism, tuberculosis, malignancy, pregnant women, and physically challenged individuals were excluded from the study. Ethical approval for the present study was obtained from the institutional ethical committee. All participants were informed about the procedure and informed written consent was taken from them.

Weight was measured to the nearest 0.1 kg using an electronic weighing scale (model 770: Seca, Germany) with the respondents lightly clothed. The height was measured using the measuring tape with respondents (without shoes) standing still by applying the direct observation method. WC was measured at the end of several consecutive natural breaths, at the level parallel to the floor, midpoint between the top of the iliac crest and the lower margin of the last palpable rib in the midaxillary line. The WC data was analyzed using cut off points for Caucasians (94 cm in men and 80 cm in women) and cut off points for Asians (90 cm in men and 80 cm in women). The BRI is calculated by using the formula:

$$BRI = 364.2 - 365.5\sqrt{1-\left[\frac{(wc/2\pi)^2}{(0.5\ height)^2}\right]}$$

The WHtR was measured using the formula WHtR = WC (cm) / height (cm). Blood pressure was measured by sphygmomanometer (OMRON 10 Series). The left arm blood pressure was measured after the individual had rested for 5 min. The average of two readings was used for analysis.

The data was analyzed using descriptive and inferential statistics. Results of the continuous measurements are presented on mean ± SD and. Analysis of variance (ANOVA) had been used to find the significance of study parameters between three or more groups of patients.

Significance was assessed at 5% level of significance. To find the significance of study parameters between three or more groups, analysis of variance (ANOVA) was used. To find the degree of relationship between study variables, the Pearson correlation was performed. Pearson correlation coefficient ranging between −1 and 1, −1 being the perfect negative correlation, 0 being the no correlation, and 1 meaning perfect positive correlation.

The p value suggestive of significance was $0.05 < p < 0.10$, moderate significance * $0.01 < p \leq 0.05$, strongly significant** $p \leq 0.01$. The data was analyzed using SPSS 18.0, and R environment ver.3.2.2.

3. RESULTS

This study was conducted on 300 apparently healthy individuals aged between 18 and 60 years.

In our study group, 70.3% had a BRI of 3-6, while 19.7% had <3 and 10% had >6 (Table 1).

It was also observed that BRI increased with age and was maximum in the age group of 41-50 years and was slightly less among the 51-60 years age group (Table 2). This observation was statistically highly significant (p value <0.001). The WC and WHtR also showed a similar trend with it increasing with age among the study group and showed maximum values in the 41-50 years age group and later slightly decreasing in 51-60 years age group. These values were also statistically significant (Table 2).

Table 1: BRI distribution of population studied.

BRI	No. of patients	%
<3	59	19.7
3-6	211	70.3
>6	30	10.0
Total	300	100.0

Table 2: Comparison of clinical variables according to age in years.

Variables	Age in years					Total	*p* value
	18-20	21-30	31-40	41-50	51-60		
SBP (mm Hg)	113.19 ± 10.7	119.07 ± 12.49	123.33 ± 8.72	122.71 ± 11.18	132.57 ± 6.90	123.32 ± 11.38	<0.001**
DBP (mm Hg)	71.63 ± 9.10	77.86 ± 10.20	79.59 ± 6.51	82.96 ± 7.63	81.55 ± 3.68	79.98 ± 8.06	<0.001**
BRI	2.87 ± 1.26	3.36 ± 1.51	4.18 ± 1.31	5.11 ± 1.01	4.82 ± 1.19	4.27 ± 1.46	<0.001**
Waist circumference	81.63 ± 12.10	85.75 ± 13.02	91.13 ± 10.21	93.53 ± 6.04	91.14 ± 10.97	89.93 ± 10.88	<0.001**
Height (cm)	170.31 ± 6.01	170.26 ± 6.14	166.63 ± 8.01	158.00 ± 5.75	158.14 ± 4.96	163.91 ± 8.34	<0.001**
Waist to height ratio	0.479 ± 0.067	0.504 ± 0.077	0.547 ± 0.062	0.592 ± 0.044	0.576 ± 0.071	0.550 ± 0.074	<0.001**

In our study, we observed a highly significant relationship between the systolic blood pressure (SBP) and BRI as well as SBP with WC and WHtR (Table 3a). These values were statistically significant. On comparing the diastolic blood pressure (DBP), we observed a highly significant relationship been the DBP and BRI as well as DBP with WC and WHtR. (Table 3b).

Presently, BMI is the most commonly calculated parameter for measuring obesity. A statistically significant increase in blood pressure was observed as the BMI in the study population increased. Therefore, when we compared the BRI, WC, and WHtR with the BMI of our study population, we found that all the parameters correlated well with the BMI also (Table 4).

A linear correlation was observed between BRI and WHtR (scatter chart). Similar positive correlation was also seen between BRI and WC. BRI, WC, and WHtR correlated well with systolic and diastolic blood pressure (Table 5, Figure 1).

Table 3a: Comparison of clinical variables with systolic blood pressure.

Variables	Systolic blood pressure			Total	*p* value
	<120 mmHg	120-149 mmHg	149-159 mmHg		
BRI	3.49 ± 1.44	4.60 ± 1.25	5.18 ± 1.29	4.27 ± 1.44	<0.001**
Waist circumference	84.60 ± 10.91	92.40 ± 9.98	94.43 ± 8.59	89.93 ± 10.88	<0.001**
Waist to height ratio	0.511 ± 0.075	0.566 ± 0.065	0.594 ± 0.057	0.550 ± 0.074	<0.001**
Height	165.99 ± 8.31	163.37 ± 8.38	158.91 ± 4.72	163.91 ± 8.33	<0.001**

Table 3b: Comparison of clinical variables with diastolic blood pressure.

Variables	Diastolic blood pressure			Total	*p* value
	<80 mm Hg	80-89 mmHg	DBP: >90 mmHg		
BRI	3.58 ± 1.48	4.71 ± 1.18	4.74 ± 1.51	4.27 ± 1.44	<0.001**
Height (cm)	165.43 ± 7.85	162.55 ± 8.57	166.15 ± 7.38	163.91 ± 8.33	0.008*
Waist circumference	84.87 ± 13.18	92.94 ± 7.08	95.05 ± 10.55	89.93 ± 10.88	<0.001**
Waist to height ratio	0.514 ± 0.082	0.573 ± 0.056	0.573 ± 0.070	0.550 ± 0.074	<0.001**

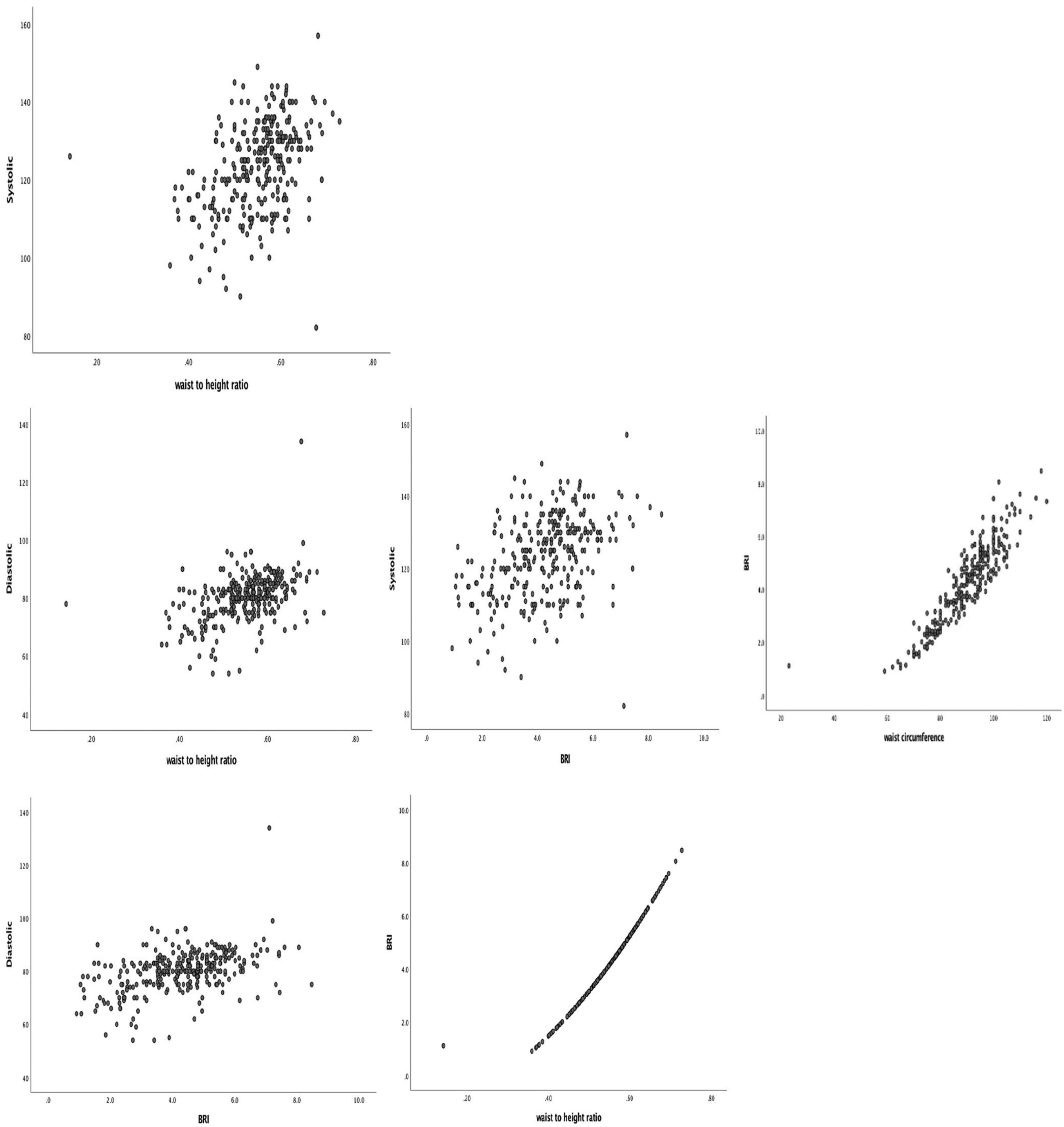
Table 4: Comparison of clinical variables with body mass index (BMI).

Variables	BMI (kg/m²)				Total	*p* value
	<18.5	18.5-22.9	23-27.5	27.5 and above		
SBP (mm Hg)	113.45 ± 9.99	114.12 ± 8.52	125.51 ± 10.05	130.67 ± 9.84	123.32 ± 11.38	<0.001**
DBP (mm Hg)	72.23 ± 9.02	75.47 ± 7.29	80.78 ± 5.62	85.69 ± 10.03	79.98 ± 8.06	<0.001**
BRI	1.88 ± 0.77	3.16 ± 1.04	4.52 ± 1.04	5.72 ± 1.17	4.27 ± 1.46	<0.001**
Waist circumference	72.68 ± 7.66	81.21 ± 6.41	91.39 ± 7.88	102.25 ± 6.64	89.93 ± 10.88	<0.001**

Table 5: Correlation between the clinical variables.

	r value	*p* value
BRI vs SBP (mm Hg)	0.425	<0.001**
BRI vs DBP (mm Hg)	0.460	<0.001*
Waist circumference vs. SBP	0.388	<0.001
Waist circumference vs. DBP	0.424	<0.001**
Waist circumference vs. BRI	0.886	<0.001**

Figure 1: Correlation between BRI, waist circumference and blood pressure.



4. DISCUSSION

Obesity is a growing epidemic. In recent years, being overweight and obesity have been the two major concerns in relation to Malaysians' health [3]. It is important to control these, as this will help to reduce complications like hypertension, diabetes, and cerebrovascular accidents. BMI has long been the standard index for measuring obesity. However, previous studies have demonstrated that the discriminative capacity of BMI is not optimal, as this calculation cannot distinguish between adipose tissue and lean body mass [5, 7]. A relatively large quantity of abdominal body fat was first identified as a predictor of obesity-related comorbidities by Vague in 1956 [8]. With the application of imaging technologies including computed tomography (CT) and magnetic resonance imaging (MRI) for the quantification of tissues in vivo, it is now well established that a higher deposition of visceral adipose tissue within the abdominal cavity is related to higher risks of obesity-related comorbidities [9]. Hence, several new indices have been developed that use some aspect of waist size or body shape in an attempt to improve on one or both of these limitations of BMI [5]. Lee *et al*. in their study on meta-analysis on indices of obesity have concluded that the statistical evidence supports the superiority of measures of centralized obesity, especially WHtR over BMI for detecting cardiovascular risk factors in both men and women [10]. A measure such as WC and its related ratios have been identified as potentially better measures of body shape and adiposity-related risks. But, the drawback of using WC is that does not correct for the fact that taller individuals have a larger waist. Advancing this idea, body indices have recently been developed that combine several of the traditional body measurements such as height, WC, and/or weight, by fitting a conjectured formula to anthropometric data like Body Shape Index (BSI) and BRI in a bid to measure the abdominal adiposity, which is blamed to cause cardiovascular complications. The BRI was first developed by Thomas *et al*. to predict the percentage of body fat and visceral adipose tissue. This index relied on waist and height eccentricity [5]. Zhang *et al.* in their study demonstrated the ability of BRI to identify arterial stiffness [11].

Our study aimed to find the relationship between BRI as well as WHtR with BP in 300 apparently healthy individuals aged between 18 and 60 years to find which is a better indicator for hypertension.

In our study group, 70.3% had a BRI of 3-6, while 19.7% had <3 and 10% had >6. Similar findings were reported by Zhang *et al.* in their study in China [11]. Further, it was found that BRI increased with age and was maximum in the 41-50 years age group. The WC also increased with age and was maximum in the 41-50 years age group. The WHtR also was found to rise with increasing age and was maximum in the 41-50 year age group. As the WC increased, the BRI also increased. All the above observations were statistically significant ($p < 0.001$).

In our study population, the average SBP was found to increase with age with maximum values in the 51-60 years age group while the DBP was maximum in the 41-50 years age group.

Our observations on correlating the systolic and the diastolic blood pressure shows a statistically significant relation with WHtR and BRI. This shows that both the parameters are good to suggest abdominal obesity and to predict hypertension. The findings of our study agrees with the observations of Richard N who in 2009 stated that obesity-related hypertension correlated with centralized obesity and that WHtR was superior to BMI, for detecting cardiovascular risk factors in both men and women [12]. Simiao Tian in their study also concluded that BRI is the best predictable anthropometric measure for hypertension and associated CVS complications, which agrees with our findings [13]. However, when we compared the BRI, WC, and WHtR with the BMI of our study population, we found that all the parameters correlated well with BMI also. Similar observation was made by Maessen MF *et al*. in their study who concluded that BRI, BMI, and WC were able to determine the presence of cardiovascular disease (CVD). Nevertheless, the capacity of BRI as a novel body index to identify CVD was not superior compared to established anthropometric indices like BMI and WC [14].

It is a well-known fact that obesity increases the risk of the development of hypertension. The factors generally considered responsible for obesity-related alterations in the pressure-natriuresis curve include enhanced sympathetic tone, activation of the renin-angiotensin system (RAS), hyperinsulinemia, and elaboration of adipokines (hormones produced in fat itself) such as leptin. A less well-understood system that may have a role in obesity and hypertension is the endocannabinoid system, as obesity is associated with increased levels of endocannabinoids in tissues and in the circulation. Structural changes in the kidney secondary to pressure of fat deposits around the kidneys, coupled with increased abdominal pressure (central obesity), has been suggested to cause disordered renal sodium reabsorption. Glycoprotein deposition in the renal medulla may contribute as well. Moreover, the hyperfiltration observed in obesity sets the stage for progressive glomerular loss and loss of renal function and associated increase in arterial pressure [12].

Obesity-related hypertension can further lead to coronary artery disease, cerebrovascular disease, renal insufficiency, atherosclerosis, left ventricular hypertrophy, atrial fibrillation, and congestive heart failure [12].

5. CONCLUSION

The findings of our study demonstrate that BRI, WC, and WHtR are good anthropometric measures that correlate well with blood pressure. Limitation of this study: Our study had a cross-sectional study design, which is not optimal for establishing a cause and effect relationship.

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Author Contributions
Both authors contributed equally to this study.

Conflict of Interest
None.

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