



Research article

Comparative evaluation of anthropometric measurements and prevalence of hypertension: community based cross-sectional study in rural male and female Cambodians



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ABSTRACT

Introduction: Hypertension is a major and preventable risk factor that can lead to cardiovascular disease. The extent that obesity impacts hypertension differs when using body mass index (BMI), waist circumference (WC) or waist to height ratio (WHtR). This study aimed to determine the prevalence of hypertension and to compare several anthropometric measurements in the prediction of hypertension between males and females from Chet Borey district of Kratie province, in Cambodia.

Methods: A cross-sectional study was conducted among 276 healthy adults aged 18 years or older, including 94 males and 182 females who visited the local health post of Kaoh chraeng in Kratie province from November 21 to 27, 2015. Systolic and diastolic blood pressures were measured. Anthropometric measures: Body mass index (BMI), as well as waist circumference (WC) and waist to height ratio (WHtR) were assessed to analyze adiposity indices. Multivariate analysis was performed to evaluate the association between anthropometric measures and hypertension among males and females after adjustment for confounders.

Results: Hypertension was more prevalent in males (38.3%) compared to females (26.4%). When considering adiposity indices, WC was higher in females than males (35.7% vs 10.6% females vs males), the same for WHtR (55.0% vs 30.9% females vs males). In the multivariate analysis, for males, in addition to high BMI [aOR 4.37 (1.01–18.81)], high WC [aOR 7.55 (1.42–39.99)] was associated with the risk of developing hypertension. Whereas for females, only WC [aOR 3.24 (1.54–6.83)] was associated with the concerned risk.

Conclusion: Prediction of hypertension using anthropometric measurements differs by sex and by the index used. In our population, BMI and WC appeared more appropriate for men while only WC was applicable to women. These results afford alternatives to hypertensive screening that may be useful tools for the majority of rural Cambodians since accessibility to health facilities is limited.

1. Introduction

Hypertension is one of the most prominent and preventable medical conditions that can lead to cardiovascular disease (CVD) and death, thus it is regarded as an important public health issue. The prevalence of hypertension has been increasing in most areas worldwide, especially in developing countries (Wolf-Maier et al., 2003). Obesity is associated with

several health problems including: hypertension, insulin resistance, and dyslipidemia, thereby increasing the risk for cardiovascular disease as well (Bouchi et al., 2016). Evidence has shown the accuracy of central obesity indices such as waist circumference (WC) and waist-to-hip ratio (WHR) as more specific predictors of CVD and metabolic syndrome (Ashwell et al., 2012; Lo et al., 2016). However, the prevalence that overweightness increases health risks differed when using body mass

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index (BMI), WC or waist to height ratio (WHtR) (Staub et al., 2018). A Brazilian study has reported that the WHtR presented a greater magnitude of association with cardiometabolic risk factors than other indices, besides having an association with Diastolic blood pressure (DBP) and high density lipoproteins (HDL) in women (Milagres et al., 2019). Cambodia is not spared by the epidemic of non-communicable diseases (NCDs) observed in the Southeast Asia region (Dans et al., 2011). A nationwide study in 2010 reported 11.2% prevalence of hypertension among the population and 43% of adult aged 55–64 years have never had their blood pressure measured (Isaakidis et al., 2011). A national STEP survey of risk factors for NCDs conducted by Department of Preventive Medicine, Ministry of Health, Cambodia in 2010 found that 10.5% of men and 16.3% of women were classified as overweight; and 11.8% of men and 16.9% of women were classified as having central obesity (Oum et al., 2010). Given its high prevalence in both urban and rural settings, the Cambodian government then designated hypertension control as a priority in the national health strategic plan. Therefore building evidence-based data for its prevention and control. The aim of this study was to first determine the prevalence of hypertension; and second to evaluate and compare several anthropometric measures in the prediction of hypertension among male and female subjects of Chet Borey rural district, province of Kratie, in Cambodia.

2. Methods

2.1. Study design and setting

The present community-based cross-sectional study collected data from the local health post of Kaoh chraeng, in Chet Borey rural district, Kratie province in the Kingdom of Cambodia.

Cambodia is a developing country located in the southern portion of the Indochinese peninsula in Southeast Asia. It is 181,035 square kilometers in area, bordered by Thailand to the northwest, Laos to the northeast, Vietnam to the east and the Gulf of Thailand to the southwest. The country is characterized by a relatively low gross domestic product (GDP), and high dependence on environmental resources, and a high poverty rate (Park, 2000; Travers et al., 2015). The agricultural sector accounts for about 35% of GDP and over 80% of the population live in rural areas (Benjamin et al., 2014). Kratie is one of the poorest provinces located in the northeast of Cambodia. It borders on Stung Treng to the north, Mondulkiri to the east, Kampong Thom and Kampong Cham to the west, and Tbong Khmum and Vietnam to the south. Kaoh Chraeng Island, in Kratie Province, Cambodia, is located in the middle of the Mekong River and has no medical centers. Five villages of the Island were the focus of study: Phum Wat with a population of 886, Phum Khalkoh with 691, Phum Kandal with 387, Phum Prek with 374, and Phum Roka Khro with 359, totaling a population of about 3000 (Figure 1a). All the five villages depend on Kaoh chraeng, health post. Access to medical care is limited because a raft is needed to leave the Island (Figure 1b) and the nearest hospital is located at 17 km away. Figure 1 describes the geographic localization of the study setting.

2.2. Data collection

From November 21 to 27, 2015, residents aged 18 or older gathered at the Health Post for medical screening, the first of its kind in Kaoh Chraeng Island (Figure 1c) and organized in collaboration with an outside organization. Demographic data collection, anthropometric measurements, blood pressure measurements and urinalysis were performed. The training session for organization of the screening and standardization of data collection was conducted according to standard operating procedure (Muntner et al., 2019). A total of 278 people were screened. Two participants who were younger than 18 years were excluded from the analysis. The final sample size was 276 subjects comprised of 94 males and 182 females.

2.3. Sample size calculation

We derived our sample size on the basis of a previously reported 20.0% prevalence central obesity for both sex among Cambodians aged from 25 to 64 years olds (An et al., 2013).

The sample size formula was:

$$n = Z_{1-\alpha/2}^2 \times p(1-p) / e^2$$

n = sample size

Z = standard normal variate (at 5% type 1 error it is 1.96)

p = expected proportion in population (based on previous and pilot studies)

e = absolute error or precision

The required minimum sample size was 245 participants.

2.4. Blood pressure (BP)

The BP of each participant, after sitting at rest for 10 min was measured twice by nurses. Measurements were taken by auscultation using a manual sphygmomanometer. The appearance of Korotkoff sounds (phase 1) was the criterion for measurement of the systolic blood pressure (SBP), and the disappearance of the Korotkoff sounds (phase 5) was the criterion for the measurement of diastolic blood pressure (DBP). SBP and DBP values were recorded as the average of two different measurements, separated by 5 min. These values were then used to assess hypertension adopting systolic and diastolic BP cutoffs of 140 mmHg and 90 mmHg, respectively, or the use of antihypertensive medication or previously diagnosed hypertension according to the JNC7 guidelines (Chobanian et al., 2003).

2.5. Anthropometric measures

Anthropometric measures were assessed by trained staff following standard operating procedures. Weight was determined with individuals wearing light clothes and no shoes on a calibrated scale. Height was also measured while individuals were barefoot using a wall-mounted meter. Body mass index (BMI), as well as waist circumference (WC) and waist to height ratio (WHtR) were measured to analyze adiposity indices. WC was assessed at the level of the umbilicus, and BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2) (Wang et al., 2015). To define central obesity based on WC, we used the recommendation of the International Diabetes Federation for South Asians as $\text{WC} \geq 90$ cm in women and ≥ 85 cm in men (Clasey et al., 1999). Likewise, according to the World Health Organization definition, definition, in relation to the BMI values, participants were classified for $\text{BMI} < 18.5$ kg/m^2 as being underweight, for $\text{BMI} 18.5 < 25$ kg/m^2 as having normal weight, for $\text{BMI} 25 < 30$ kg/m^2 as overweight and for a $\text{BMI} \geq 30$ kg/m^2 obese (Consultation, 2000; Organization, 2000).

The waist-height ratio (WHtR) was computed by dividing WC (cm) by height (cm). WHtR of ≥ 0.5 was used to define obesity dividing the population into healthy and obese (Browning et al., 2010).

2.6. Compliance with ethical standards

This study was conducted in accordance with the ethical standards established by the Helsinki declaration. The study protocol was approved by the ethical committee of Japan Health Sciences University/Kochi Medical School (approval number: 2706-1/31-185). The permission was obtained from the district Health Post of Chet Borey in Kratie province before conducting this study. To protect the patients' privacy, all data were anonymized.

2.7. Statistical analysis

Chi-square and independent t-test were performed for categorical and numerical variables respectively. Continuous variables were represented

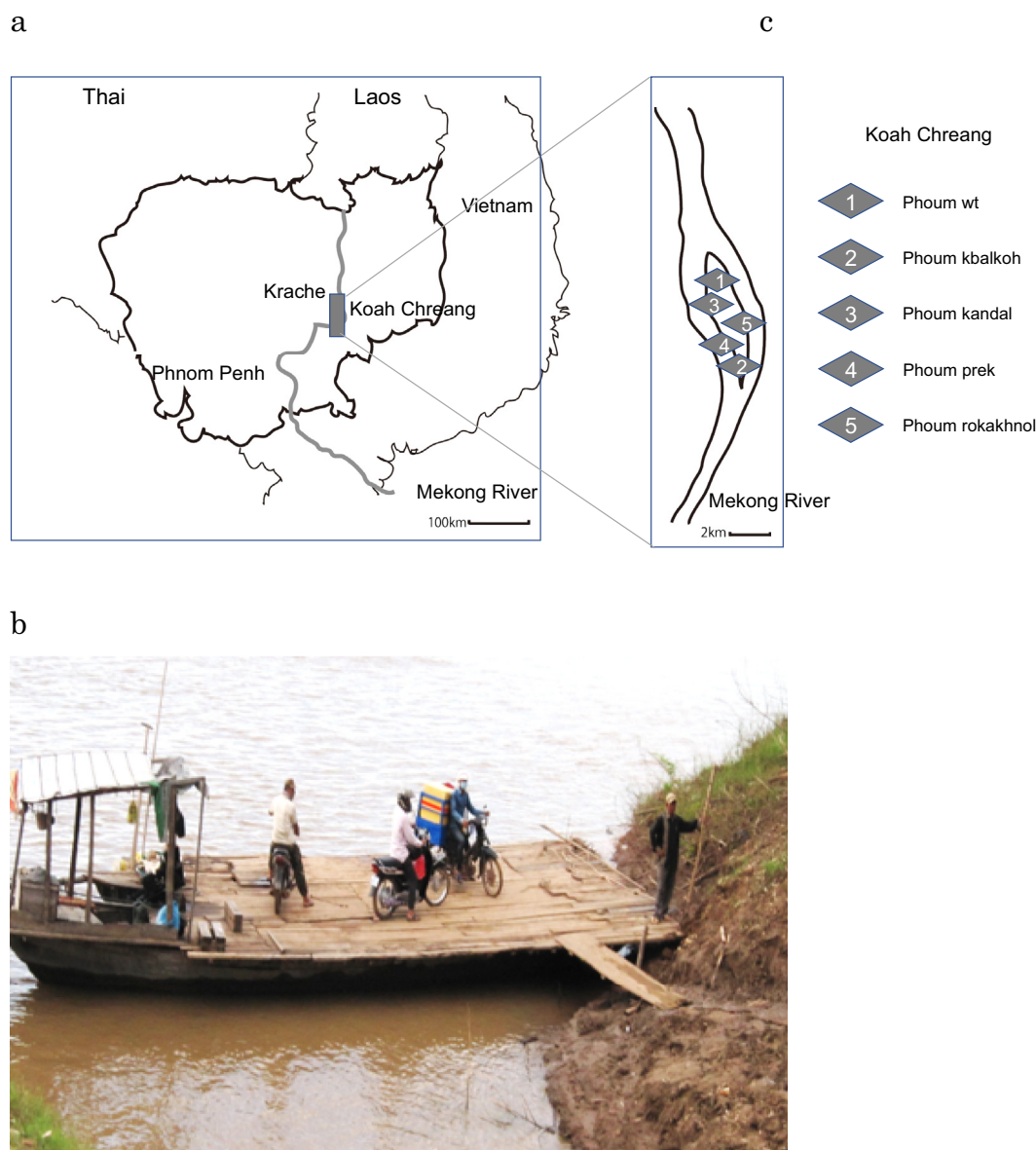


Figure 1. The location of study area, a) The distance from Kratie to Kaoh Chraeng Island is 17 km. Kaoh Chraeng Island is located in the middle of the Mekong River. Kaoh Chraeng Island has five villages. Lozenge indicates the location of the village.: 1. Phum Wat, 2. Phum Kbal Koh, 3. Phum Kandal, 4. Phum Prek, 5. Phum Roka Khnol. b) There is only one raft that leaves and arrives at the island, and is the only means of transportation for the residents. The raft serves as transportation for people, motorcycles and cars. About 40 people can get on at a time, and it runs twice a day in the morning and the evening, and other times as needed. c) The Health Post in Kaoh Chraeng Island where a physical examination was conducted.

by mean and standards deviation (mean; SD) and categorical variables by proportions (%).

In order to evaluate the association between different anthropometric measures and blood pressure, logistic regression was performed.

For analyses purposes, obesity indices were grouped as follows: for BMI, underweight, normal weight, overweight/obese; for WC, normal fat and central fat; and for WHtR, healthy, and obese.

Multivariate logistic regression analysis was performed to evaluate the association between anthropometric measures and blood pressure, after adjusting for age and income. Results are presented as adjusted odds ratios (aOR) with 95% confidence intervals (CI). Statistical significance was set at $p < 0.05$. All analyses were performed using STATA Software version 13.0 for Windows (StataCorp, College Station, TX).

3. Results

Baseline characteristics of the study population are shown in Table 1.

Among the 276 participants, 94 (34%) were males and 182 (66%) were females.

In total, 30.4% of the study population had hypertension with males (38.3%) having more hypertensive disorders than females (26.4%), $p < 0.05$. The mean age was globally at 49.6 (15.6) years, with no statistical difference by gender. Men had higher income compared to women, $p < 0.05$. When we consider anthropometric measures, women had higher WC (35.7% vs 10.6%) and higher WHtR (55.0% vs 30.9%) than men with $p < 0.01$.

Table 2 shows characteristics of the study population stratified by gender and hypertensive status. When we divided the study population according to the hypertensive status and gender, for male participants' low education (38.9%), and low income (50%) were more frequent in the hypertensive group compared to their non-hypertensive counterparts. Central fat (58.3%) and overweight/obesity assessed by BMI (29.2%) and by WHtR (70.8%) were more prevalent among hypertensive women as compared to non-hypertensive ones.

Table 1. General Characteristics of the study population.

	Male n = 94	Female n = 182	Total n = 276
Hypertension ^{†, *}	36 (38.3)	48 (26.4)	84 (30.4)
Age Mean (SD)	49.3 (16.0)	49.7 (15.4)	49.6 (15.6)
Interval of age n (%) [‡]			
18-36	25 (26.6)	38 (20.9)	63 (22.8)
37-55	28 (29.8)	78 (42.9)	106 (38.4)
56-74	38 (40.4)	54 (29.7)	92 (33.3)
≥75	3 (3.2)	12 (6.6)	15 (5.4)
Education level n (%) ^{‡, †}			
Never	16 (17.2)	43 (24.2)	59 (21.8)
Primary school	25 (26.9)	58 (32.6)	83 (30.6)
Junior high school	38 (40.9)	62 (34.8)	100 (36.9)
High school	8 (8.6)	12 (6.7)	20 (7.4)
University	6 (6.5)	3 (1.7)	9 (3.3)
Income \$/year n (%) ^{‡, †, *}			
≤500	45 (48.4)	111 (62.4)	156 (57.6)
501-1000	21 (22.6)	42 (23.6)	63 (23.3)
1001-1500	12 (12.9)	10 (5.6)	22 (8.1)
≥1501	15 (16.1)	15 (8.4)	30 (11.1)
BMI n (%) [‡]			
Underweight	20 (21.3)	30 (16.5)	50 (18.1)
Normal	64 (68.1)	118 (64.8)	182 (65.9)
Overweight/Obesity	10 (10.6)	34 (18.7)	44 (15.9)
WC n (%) ^{‡, **}			
Normal fat	84 (89.4)	117 (64.3)	201 (72.8)
Moderate/High central fat	10 (10.6)	65 (35.7)	75 (27.2)
WHtR n (%) ^{‡, **}			
Healthy	65 (69.2)	82 (45.1)	147 (53.3)
Obese	29 (30.9)	100 (55.0)	129 (46.7)

BMI, body mass index, WC, waist circumference, WHtR, waist to height ratio.

*p < 0.05, **p < 0.001.

[‡] n (%) Chi-square test.

[†] Total 5 missing values (with 1 for male and 4 for female).

Table 3 shows the odds ratios for the association between anthropometric measurements and the risk of hypertension. In total population, overweight/obese based on BMI and obese based on WHtR were two times [aOR: 2.22 (1.09–4.55)] and almost two times [aOR: 1.92 (1.08–3.42)] at risk of developing hypertension, respectively. When divided by gender, Overweight/obese men and those with central fat were four times [aOR: 4.37 (1.01–18.81)] and seven times [aOR: 7.55 (1.42–39.99)] at risk of developing hypertension, respectively.

For women, those with central fat were three times [aOR: 3.24 (1.54–6.83)] at risk of developing hypertension. In addition, before adjustment, obesity as per WHtR [OR: 2.50 (1.23–5.08)] was associated with the risk of developing hypertension in women; however, the association disappeared after adjusting for age and income [aOR: 2.11 (0.97–4.55)]. In addition, being underweight revealed to be protective against the risk of hypertension [aOR 0.22 (0.06–0.89)] in women. It is worth noting that age and income are associated with hypertension in women, suggesting that they are significant predictors of hypertension in this population, particularly in women.

4. Discussion

The present study has assessed the prevalence of hypertension and the relationship between anthropometric measures and the risk of developing hypertension by sex among the Cambodian population living in

rural areas. Hypertension was more prevalent in aged, low educated, poor people and mostly among men than women.

These findings are in accordance with the study conducted by Gupta et al. which used data from WHO STEPs survey, a nationwide survey in Cambodia (Gupta et al., 2013). Hypertension increases with age because of the increase in vascular resistance and arterial stiffness affected by one's culture and environment (Franklin et al., 1997). Factors such as obesity and insulin resistance, smoking, and changes in circulating sex hormone concentrations (menopausal) are associated with age-related inflammation and declines in nitric oxide (NO) production and bioavailability that can lead to hypertension (Krabbe et al., 2004; Torregrossa et al., 2011).

Low education and poor income in Cambodia due to various reasons such as, geographical disadvantage, late school entry, early marriage, low availability of schools, poor school facility have been previously reported in Cambodia (Velasco, 2001; Keng, 2003). In fact, Awareness, treatment, and control of hypertension are lower in participants with primary or no education, most likely reflecting a combination of low socioeconomic status, which may influence access to care (Chow et al., 2013).

When comparing neighboring countries, Brunei (48.3%), Indonesia (33.4%), and Malaysia (35.3%) have higher prevalence of hypertension than Cambodia (Lupat et al., 2016; Peltzer and Pengpid, 2018; Ab Majid et al., 2018), whereas a lower prevalence were reported in Vietnam (25%) (Son et al., 2012). Higher prevalence of hypertension in men than women has been also reported in Myanmar (31% for males versus 29% for females) (Bjertness et al., 2016).

Gender has an important influence on blood pressure, with premenopausal women having a lower arterial blood pressure than age-matched males. Sex hormones are responsible for the observed gender-associated differences in arterial blood pressure (Dubey et al., 2002) In contrast with our findings, Sadeghi et al. and Adeoye et al. reported no significant difference in hypertension between males and females (Sadeghi et al., 2019; Adeoye et al., 2017). This gap can be explained by the differences in population and settings. When we considered participants with hypertensive disorders, men had higher WC and women had higher BMI, WC and WHtR. Circulating gonadal steroids determine the sex-specific differences in adipose tissue distribution, which can be observed even after menopause (Fuente-Martín et al., 2013). Milagres et al. while studying cardiovascular risk in the elderly reported the same trends between men and women (Milagres et al., 2019). Furthermore, the elevated WHtR in the female participants can be explained by the mean age of 49.7 years which is the period of menopausal transition when the female hormonal imbalance becomes almost similar to that of men of the same age (Su and Freeman, 2009). Comparable results were reported in the United Kingdom by Malden et al. who found while studying the body fat distribution and systolic blood pressure in 10,000 adults, that men had higher WC. The high values found among males in the mentioned study could be explained by the fact that the distribution of body fat is different between the sexes, with men having on average less subcutaneous fat in android and gynoid regions but more than twice the amount of visceral android fat (Malden et al., 2019). In opposition to our findings, studies carried out in Vietnam, Iran, Nigeria, and Brazil reported higher prevalence of overweight/obesity, WC and WHtR among females than males (Cuong et al., 2007; Sadeghi et al., 2019; Adeoye et al., 2017; Dutra et al., 2018; Milagres et al., 2019).

Overall, the present study found that anthropometric measurements were associated with the risk of hypertension. The measures for adiposity, in particular BMI and WC had a higher capacity to predict individual hypertension risk among males while only WC applied for females. In alignment with our findings, several studies reported that BMI and WC are best predictors of cardiovascular diseases (Liu et al., 2019a; Dutra et al., 2018; Ashwell et al., 2012; Milagres et al., 2019; Sebati et al., 2019; Tuan et al., 2010). Of note, adiposity indices were more sensitive

Table 2. Characteristics of the study population stratified by gender and hypertensive state.

	Male		p value	Female		p value
	Hypertension			Hypertension		
	Yes n = 36	No n = 58		Yes n = 48	No n = 134	
Age Mean (SD)	52.9 (14.4)	47.1 (16.7)		57.1 (13.0)	47.0 (15.4)	<0.001
Interval of age [#]						<0.001
18-36	7 (19.4)	18 (31.0)		2 (4.2)	36 (26.9)	
37-55	11 (30.6)	17 (29.3)		18 (37.5)	60 (44.8)	
56-74	17 (47.2)	21 (36.2)		23 (47.9)	31 (23.1)	
≥75	1 (2.8)	2 (3.5)		5 (10.4)	7 (5.2)	
Education level ^{#,†}			<0.05			
Never	3 (8.3)	13 (22.8)		14 (30.4)	29 (22.0)	
Primary school	14 (38.9)	11 (19.3)		14 (30.4)	44 (33.3)	
Junior high school	11 (30.6)	27 (47.4)		16 (34.8)	46 (34.9)	
High school	5 (13.9)	3 (5.3)		2 (4.4)	10 (7.6)	
University	3 (8.3)	3 (5.3)		0 (0.0)	3 (2.3)	
Income \$/year ^{#,†}						
≤500	18 (50.0)	27 (47.4)		26 (56.5)	85 (64.4)	
501-1000	8 (22.2)	13 (22.8)		10 (21.7)	32 (24.2)	
1001-1500	5 (13.9)	7 (12.3)		2 (4.4)	8 (6.1)	
≥1501	5 (13.9)	10 (17.5)		8 (17.4)	7 (5.3)	
BMI [#]						<0.05
Underweight	8 (22.2)	12 (20.7)		4 (8.3)	26 (19.4)	
Normal	21 (58.3)	43 (74.1)		30 (62.5)	88 (65.7)	
Overweight/Obesity	7 (19.4)	3 (5.2)		14 (29.2)	20 (14.9)	
WC [#]			<0.01			<0.001
Normal fat	28 (77.8)	56 (96.6)		20 (41.7)	97 (72.4)	
Moderate/High central fat	8 (22.2)	2 (3.5)		28 (58.3)	37 (27.6)	
WHtR [#]						<0.05
Healthy	22 (61.1)	43 (74.1)		14 (29.2)	68 (50.8)	
Obese	14 (38.9)	15 (25.9)		34 (70.8)	66 (49.3)	

BMI, body mass index, WC, waist circumference, WHtR, waist to height ratio.

[#] n (%) Chi-square test.

[†] Total 5 missing values (with 1 for male without hypertension, 2 for female without hypertension and 2 for female with hypertension).

to predict hypertension in men and this is probably related to the differences of fat distribution between the genders. The mechanisms by which central adiposity may cause hypertension are not fully understood. However, there are a number of hypotheses which include insulin resistance, secretion of angiotensinogen and inflammatory cytokines by adipocytes, and accumulation of visceral adipose tissue that disturbs the renal medulla and consequently increases sodium reabsorption (De Koning et al., 2007; Landsberg et al., 2013). Partially in contrast, a study by Adeoye et al. reported that WC and WHtR did not correlate with blood pressure and BMI correlated positively with DBP in both men and women (Adeoye et al., 2017). Several other studies reported that BMI and WC are weak predictors of hypertension compared to WHtR (Liu et al., 2019b; Azimi-Nezhad et al., 2009). These differences from our study can be explained by the genetic and environmental variations among the study populations. It is well documented that ethnic and racial differences affect the determination of optimal anthropometric indicators to predict cardiovascular risk factors (Harris et al., 2000).

Underweightness was a protective factor against hypertension in women. This highlights the negative effect of higher adiposity on blood pressure as described above and confirms the general consensus on the increasing incidence of CVD as the degree of BMI increases (Grundy et al., 1999; Li et al., 2006). This result, however, is in contradiction with some reports which demonstrate that underweight people are at risk of having hypertension (Kshatriya and Acharya, 2019; Salahudeen et al., 2004). The pathophysiologic mechanisms of this paradoxical phenomenon are not well elucidated yet.

4.1. Strength

This study has the merit of evaluating and comparing the association between several anthropometric measures: WC, BMI, WHtR and blood pressure among the rural Cambodian population who have limited access to health care facilities.

4.2. Limitations

Several limitations should be considered.

First, the cross-sectional design of this study could only establish the association between the study parameters and cannot infer the causality. Thus, our findings may not be generalizable to the entire population. Follow-up studies are needed to establish the evidence of causal relationship.

Second, sampling bias may be present within our study population. The proportion of middle-aged male residents was relatively low than that of female residents (29.8% vs 42.9%; male vs female), suggesting that male residents working off the island did not visit health posts for health checkups. There is a possibility that this sampling bias caused an over estimation of strength of the association.

Third, there was a lack of information on lifestyle (e.g., alcohol consumption, smoking status, physical activity) and nutrition intake which are important factors. Although Gupta et al. reported that the levels of exercise and nutritional metrics were not significantly related to prevalence of hypertension in Cambodia (Gupta et al., 2013), other

Table 3. Association between anthropometric measures and hypertension by gender.

Foot	Male		Female		Total	
	cOR (95% CI) n = 94	aOR (95% CI) [§] n = 93	cOR (95% CI) n = 182	aOR (95% CI) [§] n = 178	cOR (95% CI) n = 276	aOR (95% CI) [§] n = 271
BMI						
Underweight	1.37 (0.48–3.85)	1.31 (0.46–3.78)	0.45 (0.15–1.40)	0.22 (0.06–0.89)*	0.81 (0.39–1.68)	0.67 (0.31–1.48)
Normal	1.00	1.00	1.00	1.00	1.00	1.00
Overweight/Obesity	4.78 (1.12–20.36) *	4.37 (1.01–18.81)*	2.05 (0.92–4.56)	1.46 (0.61–3.52)	2.35 (1.20–4.60)*	2.22 (1.09–4.55)*
Gender		-		-		1.93 (1.08–3.45)*
Interval of age		1.25 (0.76–2.07)		2.95 (1.77–4.93)***		1.88 (1.34–2.65)***
Income \$/year		0.98 (0.66–1.46)		1.66 (1.13–2.44)**		1.24 (0.95–1.63)
WC						
Normal fat	1.00	1.00	1.00	1.00	1.00	1.00
Moderate/High Central fat	8.00 (1.59–40.20)*	7.55 (1.42–39.99)*	3.67 (1.85–7.30)***	3.24 (1.54–6.83)**	2.94 (1.69–5.14)***	3.88 (2.02–7.43)***
Gender		-		-		2.72 (1.44–5.17)**
Interval of age		1.15 (0.68–1.92)		2.51 (1.54–4.07)***		1.77 (1.25–2.51)**
Income \$/year		1.06 (0.72–1.58)		1.58 (1.08–2.33)*		1.27 (0.96–1.67)
WHtR						
Healthy	1.00	1.00	1.00	1.00	1.00	1.00
Obese	1.82 (0.75–4.45)	1.65 (0.66–4.09)	2.50 (1.23–5.08)*	2.11 (0.97–4.55)	1.83 (1.09–3.07)*	1.92 (1.08–3.42)*
Gender		-		-		2.04 (1.13–3.70)*
Interval of age		1.25 (0.76–2.06)		2.53 (1.58–4.07)***		1.83 (1.31–2.57)***
Income \$/year		0.97 (0.66–1.43)		1.68 (1.15–2.46)**		1.29 (0.98–1.68)

aOR, adjusted odds ratio, cOR crude odds ratio, BMI, body mass index, WC, waist circumference, WHtR, waist to height ratio.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

[†] adjusted by interval of age, income.

[§] adjusted by gender, interval of age, income.

studies focusing on physical activities and nutritional status are needed to improve greater understanding.

Fourth, our study assessed the predictive abilities of anthropometric measures on prevalence but did not directly predict the prospective risk of high blood pressure.

5. Conclusion

In conclusion, the associations between the anthropometric measures and hypertension differed by sex, with BMI and WC being the best predictor of hypertension in men while only WC was found to be useful in women. Thus, some measurements may be useful in the screening of hypertension among the rural Cambodian population. These results reveal alternatives to hypertension screening management in the general population which are useful since their accessibility to health facilities is limited. Further studies should focus on gathering more evidence on these parameters. Nevertheless, the lifestyle changes, including physical exercise and diet that can lead to reduced anthropometric measurements may have significant public health significance as well in reducing the prevalence of hypertension within this population.

Declarations

Author contribution statement

Y. Shimotake: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

E. Mbelambela, S. Muchanga and N. Sukanuma: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

A. Villanueva: Conceived and designed the experiments; Wrote the paper.

S. Yan: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

M. Minami, R. Shimomoto and A. Lumaya: Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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