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Jacobs Journal of Obesity

Research Article

Complex Relationships between Body Mass Index and Blood Pressure in a Lean Population in Eritrea

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Received: 08-24-2015

Accepted: 09-18-2015

Published: 09-28-2015

Abstract

Background

There is diversity in patterns of body mass index (BMI)/blood pressure (BP) relationships in population based surveys. BP is generally linearly related to BMI. In some populations there is a U shaped relationship between BP and BMI. Standardized surveys using WHO stepwise approach allow for in country and inter-country comparisons for this relationship. Limited guidance is available on targeted interventions on hypertension among lean populations.

Methods

A cross sectional population based survey was conducted in 2009 to determine the prevalence of the common risk factors of the major NCDs in all the six administrative regions of Eritrea using multistage cluster sampling to reach the sample size of 6400 aged 25 to 74 years. Correlation between blood pressures and body mass index was determined.

Results

During this survey, hypertension prevalence was found to be 14% and obesity 2.5%. More than 30% of the sample was underweight making the population lean. On average, both systolic and diastolic blood pressures were positively correlated with BMI. The linear relationship between BP and BMI disappeared below the BMI of 18.5 and above 30 kg/m^2. In addition there was a U-shaped relationship between the mean diastolic blood pressure and the BMI among the under-weight.

Conclusion

The population based findings demonstrate a complex relationship between BP and BMI which have crowded an already

clouded picture. The blunting of the relationship among the obese and at low BMI calls for further interrogation before guiding policy review and targeted interventions in lean populations.

Keywords: Lean population; BMI; Hypertension

Introduction

Obesity is a key determining risk factor for non-communicable diseases [1-2]. According to the report of a WHO consultation by experts [3], obesity is considered as disease on its own right and as a key risk factor predisposing to cardio-vascular diseases including hypertension. The report recognizes body mass index (BMI) as the simple index that is commonly used to classify under-weight (BMI < 18.5 Kg/M^2), normal (BMI 18.5 – 24.99 $kg/^2$), over-weight (BMI 25 – 29.99 Kg/M^2) and Obese (BMI > or = 30 Kg/M^2) in adults. The use of BMI as the gold standard estimate for obesity is not universal with some growing reservations for its accuracy when used in athletes where increase in weight is not largely due to fat but muscle [4].

In a population based study in 2004, the prevalence of obesity in Eritrea was just 3.3% in the general population, while prevalence of under-weight was 32%, thus the Eritrean population tend to be lean [5]. In fact this makes the Eritreans the leanest population when compared to the report of the world health survey [6] carried in 51 countries including 16 African countries. The world survey found an extensively varied prevalence of underweight, overweight, and obesity on a country-by-country basis. Under-weight had a higher prevalence in Asian countries with prevalence from 11% in Pakistan to 28.9% in India. In Africa the highest under-weight prevalence was in Kenya with 14.4%, while neighboring Ethiopia had 10.8%. Higher prevalence of overweight and obesity tended to characterize Europe and the Americas. The finding of lower BMI among the Asians was confirmed [7].

Several studies have found a positive correlation between BMI and hypertension in which higher values of BMI are associated with increased prevalence of hypertension [5, 8-15]. The relationship between BMI and high blood pressure was reported to follow a linear or near linear fashion by many researchers [16-19], especially among men [20]. Associations between BMI and BP were observed to be different between Caucasian among where pulse pressure increased with increasing BMI in contrast to Asians in whom pulse pressure decreased with increasing BMI [21].

A report of a low hypertension prevalence among obese with a BMI of 30 – 40 kg/m^2 in men, was considered to be artefact presumably due to a small number of participants [11]. On the other extreme, another study reported that the relationship between BP and BMI among the underweight population group, the age-standardised prevalence of hypertension significantly increased inversely with BMI in both sexes, making a U-shaped relationship between BMI and hypertension [22]. The near unique characteristics of our population of having low prevalence of obesity and high prevalence of under-weight and hypertension (prevalence of 15.9%) [5], informed our study with the objective to determine the level of linearity of relationship between body mass index and hypertension in order to guide interventions.

Methods

Study population: A cross sectional population based survey was conducted in 2009 to determine the prevalence of the common risk factors of the major NCDs in all the six administrative Zobas (regions) of Eritrea. Persons in the age group 25 – 74 years participated. Individuals between the ages of 0-24 and above 74 years, institutionalized individuals (e.g. those in motels, hotels, hospitals, student hostels, prisons) and also non-permanent Eritrean residents were excluded from this study. Multistage cluster sampling method was applied with the guide of the WHO Stepwise approach for the NCD risk factors surveillance [23], adapted to the Eritrean context.

Data collection: Data was collected using Personal Digital Assistants (PDAs). The STEP 3 Survey method has three sequential steps to collect exposure to the NCD risk factors namely socio-demographic and behavioral information (STEP 1), Physical measurements such as height, weight, blood pressure and waist and hip circumference (STEP 2), and biochemical measurements such as total cholesterol levels, total triglycerides and fasting blood glucose in Step 3. The sequences of physical tests were Blood Pressure, Heart Rate, Height, Weight, Waist and Hip circumference in that order. Measurements were taken twice for height, weight, hip and waist circumference and three times for blood pressure, and the average was used.

Height measurement: A portable height/length measuring board (The SECA body metre; 206 seca Vogel and Halke GmbH and Co. Sonke Vogel Geschäftsführer) was used. Necessary steps were taken to ensure accuracy and the height in centimeters and the devices ID were recorded in the PDA and on the participant feedback form.

Weight measurement: A portable electronic battery operated weighing scale (A TANITA digital scale; 2003 Tanita Corporation of America Inc., Arlington Heights, IL, USA) was used for the measurement. The weight in kilograms and the device ID were recorded in the PDA and on the participant feedback form taking the necessary precaution measures to ensure accuracy.

Blood pressure measurement: OMRON automatic blood pressure monitor was used for the blood pressure measurement. The participant was asked to sit quietly for 15 minutes with legs uncrossed. The left arm of participant was placed on a table with palm facing upward and clothing rolled up. The appropriate cuff size (small, medium or large), placed 1 – 2 cm above the elbow joint was wrapped snugly onto the arm and securely fastened with Velcro. The readings for systolic and diastolic blood pressures were taken. Three measurements were taken allowing the participant to rest for 3 minutes between the readings. All readings were recorded in the PDA and the third reading was also recorded on the participant feedback form. Device ID was also recorded in the PDA.

Data Management and analysis: The data were collected using Personal Digital Assistant tools and were then downloaded and saved in a database in Microsoft Access. The files of each participant: questionnaire, body measurements, biochemistry tests and Kish data, were then merged using the participant identity number. After the data was cleaned, and weighed, they were applied to every record.

The merged and cleaned data were exported to EPI INFO Version 3.4.3 for analysis. Proportions and means with confidence interval were used in the analysis. Chi-square test was used to determine associations between variables. Further detailed statistical analysis was done using the SPSS software version 18 to see the correlation coefficients between the different NCD risk factors. Significance tests like confidence intervals for the prevalence's and means of the risk factors and p-value were calculated to see the level of statistical significance of the estimates.

BMI was calculated from height and weight. Four categories of the body mass index (BMI, kg/m^2) were defined namely: under-weight (<18.5), Normal (18.5-24.9), Over-weight (25.0-29.9) and Obesity (>= 30.0-39.9).

Hypertension was calculated from the average systolic and diastolic blood pressures using the definition (≥140/ 90mmHg). Three forms of BP were used: SBP, DBP and mean arterial pressure (MAP). MAP was calculated from the formula: MAP = DBP + $^1/_3$(SBP – DBP).

Data Quality Assurance: Eight days of consultative workshop were held for the adaption of the questionnaire followed by a 1-day consultative workshop to finalize and adopt the questionnaire. The components of the questionnaire were adapted from the core and expanded modules of STEPS 1, 2 and 3 of the WHO STEPwise approach to surveillance manual [9]. The adapted and tested questionnaires were uploaded into the PDAs and used by the data collectors as e-questionnaires.

The data collectors and supervisors were recruited from the College of Health Sciences and Ministry of Health which are experienced in data collection and research, physical measurements and collection of blood.

Five days of training were given on how to use PDAs. A pilot test was conducted to ensure the data collectors had mastered the procedures. Following the training the data collectors piloted the survey instrument for at least one day after which they shared feedback. The comments that arose from the pretest were compiled and sent to WHO/HQ/AFRO for future reference.

Ethical issues: Ethical permission was obtained from the Ministry of Health Ethics Committee prior to the commencement of the survey.

Ethical issues such as participation of the respondents, confidentiality, disclosure of health conditions, and the collection of blood samples were addressed by: (a) seeking an informed consent from the respondents prior to recruitment, during which period they were informed about their rights and that their participation was voluntary and they were free to withdraw from the survey at any point without suffering any penalty; (b) assuring the respondents of confidentiality as their names was not going to be associated with their responses particularly at the point of data analysis. Moreover, the information they gave was going to be shared with others; (c) referring respondents with raised blood pressure and/or blood glucose who were not on medications for their raised blood pressure and/or glucose to the nearest health facility; and (d) using trained and qualified health professionals for the invasive procedure of STEP 3.

Results

A total of 6234 persons responded to the survey, giving a response rate of 97%. The mean age of the respondents was 44.3 years with a standard deviation of 13.9 years. About 67% of the sample was females. A total of 6233 out of 6265 respondents (99.4%), had both their heights and weights measured. The blood pressure was measured for 6234 subjects (99.5%).

BMI distribution: The Mean BMI in (kg/m^2) in the general population was 20.4 kg/m^2 (95% CI 20.2-20.6), with no significant difference between males and female (20.1 and 20.3 kg/m^2 respectively). Prevalence of underweight (BMI≤ 18.5 kg/m^2) was 36.5% (CI,34.1-38.9), Normal weight BMI (18.5-24.9) prevalence was 51.2% (CI, 49.2-53.2), overweight (BMI 25-29.9) was 9.7% (CI=8.4-11.0) and obese (BMI >30 kg/m2) 2.5% (CI,1.9-3.1). The distribution of BMI by age group and sex is presented in Table 1.

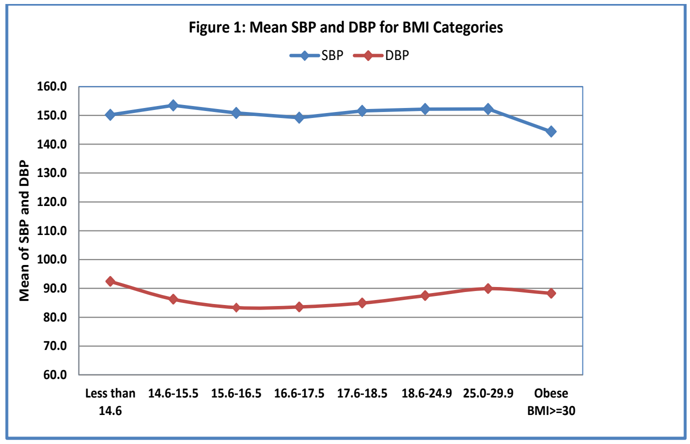
Table 1. Mean BMI by Age and Sex and Prevalence of BMI Categories.

Variable		N	Mean BMI	Standard Error of Mean
Age Group				
25-34			***19.6***	***0.1***
35-44			***20.4***	***0.1***
45-54			***20.8***	***0.1***
55-64			***20.7***	***0.1***
65-74			***20.0***	***0.1***
Sex				
Male			***20.1***	***0.1***
Female			20.3	0.0
BMI Category	N	Prevalence (%)	95%CI	
Underweight ≤18.5kg/m^2	***2274***	***38.5***	***37.2-39.7***	
Normal weight 18.5-24.9	***2969***	***50.2***	***49-51.5***	
Over weight 25-29.9	***536***	***9.1***	***37.2-39.7***	
Obese≥30kg/m^2	***130***	***2.2***	1.8-2.6	

Prevalence of Hypertension: The prevalence of hypertension in the general population was 14.1% (CI 12.9-15.3) (Table 2). Mean systolic blood pressure for the population was 115.9 mmHg (CI, 115.0-116.8), while mean diastolic blood pressure was 74.0 mmHg (CI 73.5-74.6). The prevalence of raised blood pressure, the mean systolic and the mean diastolic pressures were all higher among males at 21.1 % (CI 18.5-23.6) 123.8 mmHg (CI, 122.5-125.1) and 74.8 mmHg (CI, 74.0-75.6) respectively; than among females 12.5% (CI, 11.2-13.9), 115.9 mmHg (CI, 115.0-116.8) and 73.9 mmHg (CI, 73.0-74.0) respectively. The pressures increased with age.

Relationships between BMI and Blood Pressure: Both Systolic and diastolic blood pressures correlated positively with BMI at r= 0.173 (P = 0.00) and r = 0.245 (P value = 0.00) respectively, with a stronger correlation observed between BMI and diastolic blood pressure. As presented in table 3, positive relationship between both systolic blood pressure and diastolic blood pressure was seen in the normal BMI (18.5 -24.9 kg/m^2) and the over-weight (BMI=25-29.9 kg/m^2). In the underweight (BMI<18.5 kg/m^2) and obese (BMI>30 kg/m^2) however, there was no linearity between mean BMI and both systolic and diastolic blood pressures (Figure 1).

Figure 1. Mean systolic and diastolic blood pressures for different BMI categories..



In general as seen from Table 5, those who are underweight are less likely to develop high BP compared to those with normal BMI and obese after controlling for age, sex, waist/hip ratio, cholesterol and blood sugar. However, this relationship is true up to BMI of 15.5 kg/M^2. Below this "threshold" level BMI; BP began to rise giving a U shape relationship within the lean categories. This was true for systolic and diastolic blood pressure combined and when taken individually.

Table 2. Prevalence of High Blood Pressure by Age Group and Sex.

Ag Age Group (years)	Males			Females			Both sexes		
	n	Prev. %	95% CI	n	Prev. %	95% CI	n	Prev. %	95% CI
25 - 34	271	8.6	4.8-12.4	1525	4.2	3.0-5.3	1796	4.6	3.5-5.7
35 - 44	317	9.5	6.0-13.1	1218	8.8	7.0-10.6	1535	8.9	7.1-10.6
45 - 54	380	16.8	12.5-21.2	844	19.3	16.2-22.5	1224	18.7	16.1-21.4
55 - 64	391	24.3	19.9-28.8	547	27.0	22.4-31.6	938	26.0	22.6-29.3
65-74	354	34.4	28.3-40.6	387	40.1	34.4-45.8	741	37.2	33.0-41.5
Total	**1713**	**21.1**	**18.5-23.6**	**4521**	12.5	11.2-13.9	6234	14.1	12.9-15.3

Table 3. Regression analysis between BMI categories and systolic and diastolic Blood Pressures.

BP type	Blood pressure	R Coefficient	P-value at 95% CI
BMI<18.5 Under-weight	Systolic	0.00	0.151
	Diastolic	0.00	0.434
BMI (18.5 -25) Normal	Systolic	0.141	0.00
	Diastolic	0.173	0.00
BMI (25-29.9) Overweight	Systolic	0.1	0.076
	Diastolic	0.141	0.000
BMI>30 Obese	Systolic	0.1	0.204
	Diastolic	0.1	0.414

The obese are likely to develop higher BP compared to those with normal BMI except in the case of diastolic blood pressure where there is no significant difference.

Table 6. Variables Considered for the logistic regression analysis.

Dependent variables	**Independent Variables**	
Categorical variables	**Categorical variables**	**Continues variable**
High Blood Pressure, SBP ≥ 140 and DBP ≥ *90 mmHg*	Sex , Male and Female	Age
High Systolic BP, SBP ≥ 140 *mmHg*	High Choles-terol, Cholesterol level ≥190mg/dl	
High Diastolic BP, DBP ≥ *90 mmHg*	High Blood Sugar, Sugar level ≥110 mg/dl	
	High waist/hip ratio , waist/hip ratio≥0.90	

Table 5. Logistic regression controlling for age, sex, waist/hip ratio, cholesterol and blood sugar.

	High Blood Pressure (SBP ≥ 140 and DBP ≥ 90 mmHg)		High Systolic BP (SBP ≥ 140 mmHg)		**High Diastolic BP (DBP ≥ 90 mmHg)**	
Factors	**Exponential**	**Sig Test**	**Exponential**	**Sig Test**	**Exponential**	**Sig Test**
BMI Below 15.6 Kg/M²	0.499	0.001	.412	0.000	0.614	0.880
BMI 15.6 -16.5 Kg/M²	0.428	.000	.373	0.000	0.327	0.010
BMI 16.6 - 17.5 Kg/M²	0.567	.000	.557	0.001	0.496	0.003
BMI 17.6 - 18.5 Kg/M²	0.589	.000	.608	0.001	0.510	0.002
Obesity	1.4	.033	1.202	0.299	1.272	0.244
High Blood Sugar, Sugar level ≥110 mg/dl	1.903	.000	1.820	0.000	1.942	0.000
High Cholesterol, Cholesterol level ≥190mg/dl	1.378	.000	1.320	0.002	1.398	0.003
High waist/hip ratio , waist/hip ratio≥0.90	1.326	.003	1.297	0.011	1.232	0.100
Sex	1.085	.370	1.064	0.530	0.968	0.798
Age	1.062	0.000	1.076	0.000	1.025	0.000

The BMI groups below 15.5 kg/m2 have a higher though non-statistically significant prevalence of raised BP compared to other sub-groups within the lean cohort. This difference held true for diastolic blood pressure (Table 4). Regression analysis between body mass index and both systolic and diastolic blood pressure among the cohort of lean population showed no linear relationship with r =0.019 for SBP and r= 0.018 and respectively at P-value >0.05.

Table 4. Prevalence of hypertension, raised SBP and DPB among categories of BMI.

BMI Category	N	Prev Raised BP	CI 95%	Prev SBP	CI 95%	Prev DPB	CI 95%
Obese	130	34.6	26.5-43.5	23.5	16.7-31.6	17.6	11.6-25.1
Over weight	514	28.2	24.4-32.4	21.8	18.4-25.5	13.1	10.5-16.3
Normal weight	3057	16.8	15.5-18.2	13.3	12.2-14.6	7.2	6.4-8.2
All Lean People	2208	11.5	10.2-12.9	9.6	8.4-10.9	4.4	3.6-5.4
17.6-18.5	804	11.9	9.8-14.4	10.4	8.5-12.8	4.6	3.3-6.3
16.6-17.5	656	11.7	9.4-14.5	10.1	7.9-12.7	4.4	3.0-6.4
15.5-16.5	437	10.1	7.5-13.4	7.8	5.5-10.8	3.4	2.0-5.7
Less than 15.5	310	11.9	8.6-16.2	8.7	5.9-12.2	5.5	3.3-8.8

Discussion

The study was conducted among a large representative sample using a standard methodology. Being a follow-up study, it was an opportunity to compare with the 2004 survey on the progress made in NCDs control in Eritrea. Analysis of the results provided an opportunity to focus interventions in line with the new global plan on NCDs [24].

This study provided further evidence that the Eritrean population tended to be lean with low prevalence of obesity and high prevalence of under-weight [25]. The under-weight prevalence of 36.5% is much higher than that reported for all the African countries in the global survey and is comparable only to the Asian countries [6]. The mean BMI is much lower than that of the Americans [20]. It is also lower but comparable to the mean of about 22 kg/m^2 reported among the Chinese [11] and Asian Americans [12]. The reasons for this unique low population BMI has not been documented to the best of our knowledge. Several factors could be responsible including dietary habits, the life style of being highly mobile, environmental and genetic factors.

That hypertension is a public health problem in Eritrea has already been documented and reported [5, 26]. Interventions aimed at reducing the prevalence of hypertension have been included in the NCDs strategic plan [27]. The high prevalence of hypertension among such lean population is however what needs to be explained. Similar observation of high prevalence of hypertension among lean population has been reported among the Chinese [11].

The relationship between BMI and hypertension observed in this study were complex. First there was a general positive correlation between BMI and both systolic and diastolic blood pressures. We however, found a stronger correlation between BMI and diastolic blood pressure compared to BMI and systolic pressure, suggesting either un-explained confounding factors or a different pathophysiology.

The most significant finding of our study is the blunting of the linearity of relationship between BMI and high blood pressure at the two extremes contrary to findings of other studies [15-17]. Our findings were consistent in both regression analysis between BMI categories and systolic and diastolic blood pressures, as well as in plotting the mean systolic and diastolic blood pressures against BMI categories.

There was no correlation between BMI and both systolic and diastolic blood pressures in the obese. In addition, there was a decline in the mean systolic and diastolic blood pressure among the hypertensive the obese, compared to the overweight category. These findings are similar to those found among the Chinese where there was a decline in hypertension among persons in the 30-40 Kg/m^2 BMI range [11]. Although the Chinese study was inconclusive due to small sample size, our findings are statistically significant. Incidentally, both study populations had high proportion of lean subjects.

In our report negative correlation was noted between BMI and blood pressure among the under-weight group, which was however not statistically significant [5]. In this survey however, we found no correlation between BMI and both systolic and diastolic blood pressure in the under-weight category. The large sample however, permitted the breaking down of this category into further sub-categories and plotting the mean systolic and mean diastolic blood pressure of the hypertensive in these sub-categories. The result showed a U-shaped relationship, more visibly with the diastolic blood pressure. This

U-shaped relationship between BP and high blood pressure among the under-weight category corroborates the finding of a study among the Vietnamese population [22]. The explanation for this is unclear; however it is important to note that the two populations were both lean. This is further evidence for the need to study the pathophysiology of hypertension among the lean populations.

In conclusion, the findings of our study suggest that, in implementing interventions for NCDs control, the screening for high blood pressure in Eritrea should be based on other factors and should be done regardless of BMI. The high prevalence of persons classified as under-weight calls for a nomogram study to re-define the normal for this population. The complex relationship between BMI and hypertension advocates the need for further studies on the pathophysiology of hypertension among lean population groups. This is in line with a previous suggestion that the findings of different patterns of relationships between BMI and hypertension among Caucasians and non-Caucasians suggest a different pathology and therefore different interventions

Conflict of Interest

There is NO conflict of interest to disclose.

Acknowledgements

The Eritrean NCD Risk Factors STEPS Report is a record of a combined effort of several organizations and individuals, particularly the Ministry of Health, World Health Organization, and World Diabetes Foundation (WDF). Acknowledgement is also due to Mr. Fitsum (MOH), Mr. Zeccarias Andemariam (MOH), Ms Leanne Riley, Ms Melanie Cowan (WHO/HQ), Alisalad Abdikamal (WHO/AFRO), Dr Idrissa Sow former WR/Eritrea, and Dr. Samai Mohammed (WHO Consultant).

Summary Table:

What is known about the topic	There is a positive relationship between hypertension and body mass index (BMI)
	Hypertension prevalence is high even among lean population
What this study adds	Hypertension prevalence does not increase with BMI beyond the obesity cut off
	Hypertension prevalence does not decrease with further decrease in BMI after a threshold
	Diastolic blood pressure has a U shaped relationship with BMI among the under-weight in a lean population

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