Association of anthropometric indices of obesity with hypertension among public employees in northern Ethiopia: findings from a cross-sectional survey

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ABSTRACT

Objectives The burden of hypertension is increasing in low-income countries, including Ethiopia. Obesity is widely known to be associated with hypertension, but different anthropometric indices of obesity might differ in association with hypertension, which is largely unknown in northern Ethiopia.

Design Data from our previous cross-sectional epidemiological survey were statistically analysed.

Setting Public employees in the regional capital city in northern Ethiopia.

Participants The data of 1380 participants (823 men and 557 non-pregnant women) aged 25 and 64 years were analysed.

Outcome measures The presence of hypertension was the outcome measure and multivariable-adjusted logistic regression analyses were used to investigate the association of body mass index (BMI), waist circumference, and waist–hip ratio in men and women separately. The area under the curve (AUC) for three anthropometric indices for discriminating hypertension was also obtained. Separate analyses were conducted for waist circumference and waist–hip ratio analyses further adjusted for BMI.

Results BMI was linearly associated with hypertension in men (OR for 1 SD increase in BMI 1.45, p=0.001) and women (OR for 1 SD increase in BMI 1.41, p=0.01). The association of waist circumference was independent of BMI both in men (OR for 1 SD increase in waist circumference: 1.57, p=0.029). The association of waist–hip ratio with hypertension adjusted for BMI was significant in men (OR for 1 SD increase in the waist–hip ratio: 1.46, p=0.001), but was weak and non-significant in women. The AUC for BMI was 0.64 in men and 0.67 in women, while AUC for waist circumference was 0.69 both in men and women.

Conclusions Waist circumference was associated with hypertension independent of BMI among public employees in northern Ethiopia.

INTRODUCTION

Hypertension is a major global public health concern, accounting for 10.8 million deaths in 2019 globally. The WHO reported that the age-standardised prevalence of hypertension in low-income and middle-income countries was higher than that in high-income countries.

Ethiopia is a low-income country in sub-Saharan Africa with over 102 million populations and experienced over 10% of annual economic growth in the past decade. While communicable diseases are still prevalent, non-communicable diseases (NCD) accounted for 39% of all deaths in Ethiopia in 2018. A nationwide NCD risk factor survey in 2015 reported that the prevalence of hypertension was 15.7% in men and 16.5% in women, and a recent survey conducted in southern Ethiopia reported 19.3% in men and 14.2% in women as well. Prevention and control of hypertension are urgently required in countries such as Ethiopia, of which healthcare systems are yet insufficient to manage cardiac diseases and stroke, or serious consequences of hypertension.
Since the data and information on the prevalence of NCD risk factors were still scarce in northern Ethiopia, we conducted a cross-sectional epidemiological study on NCD risk factors13 and a qualitative study on perception and attitude towards NCD risk factors14 among public employees in a regional capital city in northern Ethiopia. Our epidemiological study showed that the age-standardised prevalence of hypertension was 22.4% in men and 15.3% in women.

Obesity is a well-known determinant factor of hypertension.15–17 Anthropometric indices of obesity include body mass index (BMI), waist circumference, and waist–hip ratio, and the latter two indices are supposed to indicate the degree of abdominal obesity.18 As obesity is one of the most important determinants of hypertension,15–17 public health efforts to prevent and control excess weight need to be strengthened19 together with other measures such as reducing salt intake.20 Appropriate anthropometric indices need to be identified to monitor the progress of such public health interventions, as different anthropometric indices might have a different association with hypertension. Previous studies in England, Iran, Sweden and Brazil showed that the association of BMI, waist circumference and waist–hip ratio with hypertension, but the findings were not consistent among the studies.21–24 A study in southern Ethiopia examined the predictability of anthropometric indices for hypertension, without adjusting for age and other behavioural factors.15 However, the difference in association with hypertension among anthropometric indices has not yet been investigated in northern Ethiopia.

Thus, we examined the associations of BMI, an index of general obesity, and the anthropometric indices of abdominal obesity, which were waist circumference and waist–hip ratio with hypertension. This study aimed to explore the difference in association with hypertension among anthropometric indices of obesity, including BMI, waist circumference and waist–hip ratio, among public employees in northern Ethiopia.

METHODS

Data source

We used the dataset obtained from the cross-sectional epidemiological survey of NCD risk factors conducted between October 2015 and February 2016, targeting public employees between 25 and 64 years of age in a regional capital city in northern Ethiopia. The details of the survey were described elsewhere.13 In total, 1527 participants (869 men and 658 women) partook in the study. Excluding pregnant women (n=22), individuals younger than 25 years old (n=98), and individuals whose age or sex was unknown (n=27), the data of 1580 participants (823 men and 557 women) were statistically analysed.

Variables

Hypertension was defined as systolic blood pressure (SBP) ≥140 mm Hg and diastolic blood pressure (DBP) ≥90 mm Hg. SBP/DBP <120/80 mm Hg was considered as normal.25–27

BMI, calculated as weight in kilograms divided by height in metres squared, was categorised into five groups: <21.0, 21.0–22.9, 23.0–24.9, 25.0–27.4 and ≥27.5 kg/m². We collapsed the <18.5 and ≥30 kg/m² category, underweight and obesity according to the WHO definition, and merged them with the adjacent categories. Waist circumference was categorised into five groups: ≤80.9, 81.0–84.9, 85.0–90.9, 91.0–94.0 and >94 cm. Waist–hip ratio was categorised into four groups: <0.80, 0.81–0.84, 0.85–0.89 and ≥0.90.

Age, marital status, income, smoking, khat chewing, alcohol drinking, fruit and vegetable intake were considered as covariates. All the variables were categorised as dichotomised groups except age which was continuous: income, ≥3001 and <3000 Ethiopian birrs per month on average; marital status, currently married and single/separated; smoking/khat chewing, ever smoked/chewed and never smoked/chewed; alcohol drinking, 1–7 and <1 day per week; fruit and vegetable intake, ≥3 and <3 servings per day.

Statistical analysis

Age-adjusted proportion (%) of sociodemographic and behavioural variables, estimated using the general linear model, was demonstrated according to BMI, waist circumference and waist–hip ratio categories according to sex. The binominal logistic regression model was applied to explore the relationship of different anthropometric indices with hypertension. The logistic regression models for three anthropometric variables were initially adjusted for age (continuous) only. Subsequently, further adjustment was done for the following covariates for each anthropometric variable: income, marital status, smoking, khat chewing, alcohol drinking and fruit and vegetable intake. For the analyses of waist circumference and waist–hip ratio analyses, continuous BMI was also adjusted on top of the aforementioned covariates. The linear association of the three anthropometric indices with hypertension was evaluated using the continuous variables. In each model, the OR for the increment of 1 SD BMI, 1 SD waist circumference, 1 SD waist–hip ratio was presented with the corresponding 95% CI. In addition, the area under the receiver operating characteristic curve was calculated using univariable logistic regression. It is equivalent to c-index, an overall measure of discrimination indicating the ability of a model (the variable) to distinguish individuals who have hypertension from those who do not.28 The area under the curve (AUC) was presented along with the 95% CI to aid our comparison among three anthropometric variables. All the analysis was conducted using SPSS software V.23.0.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

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RESULTS
The mean age was 39.5 years (mean age ±SD: 39.5±9.4). The mean SBP was 119.6 mm Hg (mean SBP ±SD: 119.6±16.7), and the mean DBP was 80 mm Hg (mean DBP ±SD: 79.9±9.9). The overall prevalence of hypertension was 19.6% (22.4% in men and 15.3% in women).

The age-adjusted proportion of having average monthly income ≥3001 Ethiopian birrs was 52.1% in the lowest BMI group, and 74.1% in the highest BMI group in men, whereas, 57.0% and 73.7% in the lowest and highest BMI groups respectively in women (table 1). Similarly, the age-adjusted proportion of married, ever smoking/khat chewing, alcohol drinking, ≥3 servings of fruit and vegetable intake increased from the lowest to the highest BMI groups both in men and women. Similar findings were observed in the age-adjusted proportions of these covariates according to waist circumference and waist–hip ratio (online supplemental table 1 and 2).

BMI, waist circumference and waist–hip ratio were significantly associated with hypertension both in men (table 2) and women (table 3). In men, BMI was linearly associated with hypertension (OR for 1 SD BMI: 1.45, p=0.001) significantly, and the OR of having hypertension was 2.92 (95% CI 1.46 to 5.83) in the highest BMI category compared with the lowest category (multivariable adjusted model). Similarly, waist circumference was linearly associated with hypertension (OR for 1 SD increase in waist circumference: 1.67, p<0.001), and the association was independent of BMI (OR for 1 SD waist circumference: 1.74, p=0.002). The waist–hip ratio was also linearly associated with hypertension (OR for 1 SD increase in the waist–hip ratio: 1.56, p<0.001). The association was also significant after further adjustment for BMI (OR for 1 SD increase in the waist–hip ratio: 1.46, p<0.001).

In women, BMI was also linearly associated with hypertension (OR for 1 SD BMI: 1.41, p=0.011). The OR of having hypertension in the highest BMI category was 3.68 (95% CI 1.62 to 8.39) compared with the lowest category in multivariable adjusted model. Waist circumference was linearly associated with hypertension (OR for 1 SD increase in waist circumference was 1.70, p=0.001). This association was also independent of BMI (OR for 1 SD increase in waist circumference: 1.57, p=0.029). The waist–hip ratio was linearly associated with hypertension only in the age-adjusted model (OR for 1 SD increase in the waist–hip ratio: 1.31, p=0.030). The association was obscured after adjustment for variables in multivariable adjusted model (OR for 1 SD waist–hip ratio: 1.31, p=0.056), and after further adjustment for BMI (OR for 1 SD waist–hip ratio: 1.25, p=0.13) in multivariable adjusted and continuous BMI adjusted model.

The AUC for BMI was 0.64 in men and 0.67 in women (table 4). AUC for waist circumference was 0.69 both in men and women, and AUC for the waist–hip ratio was 0.70 in men and 0.64 in women.

DISCUSSION
This study examined the association of obesity measured by anthropometric indices with hypertension among public employees in northern Ethiopia. BMI, waist circumference and waist–hip ratio were associated with hypertension independent of socioeconomic and behavioural variables in men. Waist circumference was associated with hypertension independent of BMI both in men and women; however, the waist–hip ratio was associated with hypertension independent of BMI only in men but not women. As far as we know, this is the first study
weaker association of waist–hip ratio with hypertension, the lowest in women in the present study. The lack of, or the three anthropometric indices of obesity in men, but Indeed, the AUC of waist–hip ratio was the highest among and England, 21 in which no sex difference was observed.


to investigate the difference of anthropometric indices of obesity in association with hypertension in northern Ethiopia.

It is well established that the degree of obesity measured by various anthropometric indices was associated with hypertension.15–17 Similar to our findings, BMI and waist circumference were associated with hypertension in northern Ethiopia,15 China,29 Iran22 and England 21 although regardless of sex, was reported by others as well.29 30 These findings might indicate that the waist–hip ratio could be a predictor of hypertension only in men in this population. Sex difference in the association between waist–hip ratio and hypertension shown in this study might be due to the sex difference in body fat distribution, or predominant subcutaneous fat distribution in women,31 and to the lower prevalence of increased waist circumference and increased waist–hip ratio in women than men in this population,13 but further studies are certainly required.

This study found that abdominal obesity measured by waist circumference was associated with hypertension independent of BMI while BMI was not significantly associated with hypertension after adjusted for waist circumference (data not shown). We also found that the AUC of waist circumference was higher than the AUC of BMI both in men and women, although the difference was not so much. These findings indicated that waist circumference could be a better predictor of hypertension than BMI consistent with previous studies.32–34 However, some studies reported inconsistent findings: a meta-analysis of studies conducted in the Asia-Pacific region

### Table 2: OR and 95% CI of body mass index (BMI), waist circumference, and waist–hip ratio with hypertension in men

| BMI, kg/m²   | <21.0 | 21.0–22.9 | 23.0–24.9 | 25.0–27.4 | ≥27.5 | OR 1 |
|-------------|-------|-----------|-----------|-----------|-------|------|
| n of cases/N | 25/223| 38/179    | 46/185    | 45/151    | 29/80 |      |
| Age-adjusted OR | 1     | 1.67 (0.94 to 2.94) | 2.15 (1.24 to 3.73) | 2.49 (1.42 to 4.37) | 3.20 (1.69 to 6.07) | 1.32 (1.10 to 1.57) |
| Multivariable adjusted OR | 1     | 1.27 (0.70 to 2.33) | 1.87 (1.04 to 3.33) | 2.06 (1.12 to 3.80) | 2.92 (1.46 to 5.83) | 1.45 (1.17 to 1.78) |

| Waist circumference, cm | <80 | 81.0–84.9 | 85.0–90.9 | 91.0–94.0 | >94 | OR 2 |
|------------------------|-----|-----------|-----------|-----------|-----|------|
| n of cases/N | 17/175 | 17/118 | 27/159 | 24/111 | 100/254 |      |
| Age adjusted OR | 1 | 1.35 (0.65 to 2.80) | 1.55 (0.80 to 3.01) | 1.86 (0.93 to 3.72) | 3.98 (2.22 to 7.11) | 1.74 (1.43 to 2.12) |
| Multivariable adjusted OR | 1 | 1.11 (0.51 to 2.41) | 1.30 (0.65 to 2.57) | 1.41 (0.67 to 2.96) | 3.30 (1.78 to 6.10) | 1.67 (1.35 to 2.07) |
| Multivariable adjusted+continuous BMI adjusted OR | 1 | 0.99 (0.44 to 2.22) | 1.24 (0.60 to 2.53) | 1.34 (0.60 to 2.99) | 2.96 (1.34 to 6.54) | 1.74 (1.22 to 2.47) |

| Waist–hip ratio >0.80 | 0.81–0.84 | 0.85–0.89 | ≥0.90 | OR 3 |
|----------------------|-----------|-----------|-------|------|
| n of cases/N | 5/58 | 10/94 | 21/165 | 141/414 |      |
| Age-adjusted OR | 1 | 1.27 (0.41 to 4.00) | 1.32 (0.46 to 3.74) | 3.47 (1.32 to 9.11) | 1.61 (1.33 to 1.95) |
| Multivariable adjusted OR | 1 | 1.11 (0.33 to 3.68) | 1.42 (0.49 to 4.08) | 3.16 (1.18 to 8.45) | 1.56 (1.28 to 1.91) |
| Multivariable adjusted+continuous BMI adjusted OR | 1 | 1.14 (0.34 to 3.83) | 1.35 (0.46 to 3.92) | 2.59 (0.95 to 7.06) | 1.46 (1.19 to 1.78) |
did not suggest the existence of systematic differences among different anthropometric variables in their relation to hypertension. Several studies found a stronger association of BMI with hypertension than waist circumference. The reasons for such discrepancies among previous studies are not clear but it might be in part due to the difference in the ethnicity, sex, or targeted age groups among these studies as the inter-individual variation in the degree of abdominal obesity might be limited in some of these studies.

Table 3  OR and 95% CI of body mass index (BMI), waist circumference, and waist–hip ratio with hypertension in women

| BMI, kg/m² | <21.0 | 21.0–22.9 | 23.0–24.9 | 25.0–27.4 | ≥27.5 | OR 1 |
|-----------|------|----------|----------|----------|-------|------|
| n of cases/N | 25/223 | 38/179 | 46/185 | 45/151 | 29/80 |      |
| Age-adjusted OR | 1 | 2.06 (0.90 to 4.70) | 2.06 (0.95 to 4.50) | 1.46 (0.65 to 3.27) | 4.25 (2.08 to 8.66) | 1.47 (1.15 to 1.86) |
| Multivariable-adjusted OR | 1 | 1.96 (0.81 to 4.76) | 1.82 (0.77 to 4.31) | 1.49 (0.61 to 3.65) | 3.68 (1.62 to 8.39) | 1.41 (1.08 to 1.84) |

| Waist circumference, cm | <80 | 81.0–84.9 | 85.0–90.9 | 91.0–94.0 | >94 | OR 2 |
|-------------------------|-----|----------|----------|----------|-----|------|
| n of cases/N | 17/175 | 17/118 | 27/159 | 24/111 | 100/254 |      |
| Age-adjusted OR | 1 | 1.57 (0.62 to 3.93) | 1.54 (0.65 to 3.68) | 2.91 (1.30 to 6.49) | 3.52 (1.75 to 7.07) | 1.71 (1.30 to 2.26) |
| Multivariable-adjusted OR | 1 | 1.52 (0.56 to 4.12) | 1.66 (0.64 to 4.28) | 2.63 (1.07 to 6.48) | 3.08 (1.35 to 7.04) | 1.70 (1.23 to 2.34) |
| Multivariable adjusted+continuous BMI adjusted OR | 1 | 1.36 (0.49 to 3.73) | 1.41 (0.53 to 3.76) | 2.14 (0.83 to 5.53) | 2.27 (0.88 to 5.88) | 1.57 (1.05 to 2.35) |

| Waist–hip ratio | >0.80 | 0.81–0.84 | 0.85–0.89 | ≥0.90 | OR 3 |
|----------------|-------|----------|----------|-------|------|
| n of cases/N | 5/58 | 10/94 | 21/165 | 141/414 |      |
| Age-adjusted OR | 1 | 0.94 (0.38 to 2.30) | 1.36 (0.61 to 3.03) | 2.28 (1.09 to 4.76) | 1.31 (1.03 to 1.67) |
| Multivariable-adjusted OR | 1 | 1.03 (0.39 to 2.76) | 1.14 (0.46 to 2.82) | 2.15 (0.95 to 4.89) | 1.31 (0.99 to 1.73) |
| Multivariable adjusted+continuous BMI adjusted OR | 1 | 0.97 (0.36 to 2.63) | 1.07 (0.43 to 2.65) | 1.88 (0.81 to 4.36) | 1.25 (0.94 to 1.67) |

n indicates number of hypertension within the category; N indicates number of people within the category. Multivariable adjusted: adjusted for age, income, marital status, smoking, khat chewing, alcohol drinking and fruit and vegetable intake. Multivariable adjusted+continuous BMI adjusted: adjusted for age, income, marital status, smoking, khat chewing, alcohol drinking, fruit and vegetable intake and continuous BMI.

OR 1, OR for 1 SD body mass index with 95% CI; OR 2, OR for 1 SD waist circumference with 95% CI; OR 3, OR for 1 SD waist hip ratio with 95% CI.

Table 4  The area under the receiver operating characteristic curve for the relationship between hypertension and anthropometric indices (unadjusted)

| | Area under the curve (AUC) | SE | 95% CI |
|----------------------------|-----------------------------|-----|--------|
| Men                        |                             |     |        |
| Body mass index            | 0.64                        | 0.02 | 0.59 to 0.68 |
| Waist circumference        | 0.69                        | 0.02 | 0.65 to 0.74 |
| Waist–hip ratio            | 0.70                        | 0.02 | 0.66 to 0.75 |
| Women                      |                             |     |        |
| Body mass index            | 0.67                        | 0.03 | 0.61 to 0.73 |
| Waist circumference        | 0.69                        | 0.03 | 0.58 to 0.71 |
| Waist–hip ratio            | 0.64                        | 0.03 | 0.63 to 0.75 |
Our study found that waist circumference was significantly associated with hypertension after adjustment for BMI. This indicates that changes in waist circumference should be monitored during the hypertension control interventions, such as diet management and physical exercise, rather than just monitoring body weight. Waist circumference can be measured even in a resource-poor setting in developing countries. Also, regular screening of BMI and waist circumference would be useful to predict risks of hypertension.

The strength of our study is that we, for the first time, examined the difference of anthropometric indices of obesity in association with hypertension in northern Ethiopia. We applied logistic regression models adjusted for socioeconomic and behavioural variables and further adjusted for BMI to explore the association of anthropometric indices of obesity with hypertension. The findings of the current study could be a basis for hypertension control programmes in northern Ethiopia, which we piloted previously. The limitation of this study is that the nature of a cross-sectional study, causal relationships could not be identified. Another limitation is that there might be interobserver errors in measuring waist circumference and hip circumference. However, anthropometric indices were measured by well-trained data collectors following the WHO standard protocol, so such errors were likely to be minimum.

In conclusion, the current study showed that the association of waist circumference with hypertension was independent of BMI among northern Ethiopian public employees. Abdominal obesity measured by waist circumference could be a good predictor of hypertension in this population.

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