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Published in:
Tropical Medicine and International Health

DOI:
10.1111/tmi.13149

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

VOLUME 23 NO 11 PP 1176–1187 NOVEMBER 2018

Risk factors of pre-hypertension and hypertension among non-pregnant women of reproductive age in northeastern Tanzania: a community based cross-sectional study

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Abstract

OBJECTIVES To determine risk factors of pre-hypertension and hypertension in a cohort of 1247 rural Tanzanian women before conception.

METHODS Demographic and socioeconomic data, anthropometric measurements, past medical and obstetric history and other risk factors for pre-hypertension and hypertension were collected using a structured questionnaire. Multiple logistic regression analysis was used to evaluate the associations between anthropometric indices and other risk factors of pre-hypertension and hypertension. The predictive power of different anthropometric indicators for identification of pre-hypertension and hypertension patients was determined by Receiver Operating Characteristic curves (ROC).

RESULTS The median (range) age was 28.0 (18–40) years. The age-standardised prevalences of pre-hypertension and hypertension were 37.2 (95% CI 34.0–40.6) and 8.5% (95%CI 6.7–10.8), respectively. Of hypertensive patients (n = 98), only 20 (20.4%) were aware of their condition. In multivariate analysis, increasing age, obesity and haemoglobin levels were significantly associated with pre-hypertension and hypertension.

CONCLUSION Despite a low prevalence of hypertension, over one third of the women had pre-hypertension. This poses a great challenge ahead as pre-hypertensive women may progress into hypertension as they grow older without appropriate interventions. Obesity was the single most important modifiable risk factor for pre-hypertension and hypertension.

keywords Pre-hypertension, hypertension, women, reproductive age, Tanzania

Introduction

Cardiovascular diseases (CVDs), a major subgroup of non-communicable diseases (NCDs), are an emerging public health problem in sub-Saharan Africa (SSA) [1–4]. Hypertension (HT), a major risk factor of CVDs, is a highly prevalent chronic medical condition affecting over 1.5 billion people and the leading cause of cardiovascular mortality worldwide [5]. Hypertension is defined when blood pressure (BP) reaches 140/90 mmHg or greater, but the risk of CVDs increases progressively for each increment of systolic blood pressure (SBP) above 115 mmHg and or diastolic BP (DBP) above 75 mmHg and SBP ranges of 120–139 mmHg and/or diastolic BP (DBP) of 80–89 mmHg have been defined as pre-hypertension (pre-HT) [6].

Numerous studies in SSA report the burden of HT in the general population [3, 4, 7–9], but its epidemiology among women of the reproductive age is not well known. Few existing studies have reported prevalence rates ranging from 18.6% in urban Zambia, but as low as 6.7% in rural Zambia [10] to 8.3% in urban Ethiopia [9]. Furthermore, the majority of HT patients in SSA are unaware of their condition [3, 4, 8, 11] and without appropriate interventions; many pre-HT individuals may progress into HT as they grow older [12–14].

Although in general, women of reproductive age have relatively low rates of HT, HT presents important clinical

implications and challenges in this population, not only because of its role as a risk factor for CVDs, but also because of issues associated with HT during pregnancy [15–18]. HT during pregnancy has been associated with abortion [18], preterm delivery, foetal growth restriction, abruptio placenta and perinatal mortality [15, 17]. Furthermore, without appropriate intervention, 20–50% of hypertensive women will develop super imposed preeclampsia [17, 19].

The association between traditional risk factors such as increased age, obesity, physical inactivity, smoking and alcohol consumption with pre-HT and HT has been studied in detail among elderly women [3, 4, 7, 9], but less is known among women of the reproductive age in SSA. For instance, obesity and overweight, major risk factors of HT, disproportionately affect more women than men in SSA [1]. Finally, both pre-HT and HT and haemoglobin (Hb) levels affect pregnancy outcomes [17] and there are indications that both SBP and DBP may increase with increasing Hb levels. This association has been widely investigated among Caucasians and Asians but with conflicting results [20–24]. Few studies among Africans have all shown a positive association between increasing Hb with BP [25, 26].

Preconception care services are rarely available in rural Tanzania. Many HT women are therefore likely to enter pregnancy with inadequatetly controlled pressure, putting themselves and their foetus at risk. Hence, establishing optimal blood pressure before conception has important health benefits for the mother and foetus during pregnancy. The aim of this study was to determine the risk factors for pre-HT and HT among non-pregnant women of the reproductive age before conception in order to provide information needed to improve women's health for better pregnancy outcomes.

Methods

Study setting and population

This study was conducted as part of a community-based epidemiological study 'Foetal exposure and epidemiological transition - the role of anaemia in early life for non-communicable diseases in later life (FOETALforNCD)' conducted in Korogwe and Handeni Districts, Tanga Region, Tanzania. The overall objective of the FOETALforNCD study was to evaluate the effects of anaemia before and during early pregnancy on foetal growth alterations, placental development and susceptibility to non-communicable diseases (NCDs). In order to achieve this objective, we enrolled women before conception (pre-pregnancy cohort) and pregnant women in their first 14 weeks of gestation (pregnancy cohort). The present analysis utilised baseline data from a subgroup of women who were enrolled before conception and BP measured at the time of enrolment.

Eligibility criteria

The inclusion into the pre-pregnancy cohort was based on the likelihood of conception during the study period. This included women aged 18–40 years, trying or planning to become pregnant or women who were not using modern contraceptives (except condoms) irrespective of pregnancy wishes. We excluded all women with babies aged less than nine months, and women with subfertility, defined as failure to conceive for two or more consecutive years despite trying to become pregnant.

Participants' identification, preconception enrolment and follow-up

Village leaders and community members were informed about the study in meetings. Trained fieldworkers visited each household, enumerated all women aged 18–40 years and issued invitation cards for them to visit the nearby health facility for screening and enrolment. Other efforts included screening women who were seeking other health care services.

After enrolment, women were asked to report immediately to the study team if they suspected to be pregnant; otherwise they would be followed up once in every 3 months for general health check-ups and urine for pregnancy testing. Upon conception transabdominal ultrasound (5–2 MHz abdominal probe, Sonosite TITAN® and Sonosite Turbo®, US High resolution, Sonosite, Bothell, WA, USA) was used to estimate gestational age (GA) [27, 28].

Data collection

A structured questionnaire was used to collect demographic and socioeconomic data (education level, occupation, and marital status, type of toilet facility and main source of water for domestic use), previous medical and obstetric history, family history of NCDs and other potential risk factors for pre-HT and HT.

Height was measured using a stadiometer (Seca GmbH & Co. KG., Hamburg, Germany). Weight was measured using digital weighing scales (Seca GmbH & Co. KG., Hamburg, Germany). Body mass index (BMI) was defined as weight in kilograms divided by the square of the height in meters (kg/m^2) and categorised as underweight (BMI <18.5 kg/m^2), normal weight (BMI 18.

5–24.9 kg/m^2), overweight (BMI 25.0–29.9 kg/m^2), and generalised obesity (BMI ≥30 kg/m^2) according to the WHO cut-off standards [29]. Waist circumference (WC) was measured by placing a tape at the midpoint between the last rib and the top of the iliac crest. Hip circumference was measured at the point yielding the maximum circumference over the buttocks. Waist-to-hip ratio (WHR) was calculated as WC divided by hip circumference and central obesity defined as WC ≥80 cm or WHR ≥0.85 [29].

Blood pressure was measured using a digital BP monitor (r-champion® N, Rudolf Riester, Jungingen, Germany) with an inflatable cuff of appropriate size placed on mid-upper arm circumference [30] with a woman in a sitting position and after resting for at least 5 min. The first BP reading was taken on both upper arms. The arm with the highest BP was used as the reference arm. The second BP measurement was taken from the reference arm and final BP defined as the average of the two readings from the reference arm [30]. Pre-HT was defined as BP of 120 to 139 mmHg and/or DBP of 80 to 89 mmHg [6]. Pre-HT women received health education. Hypertension was defined as SBP ≥140 mmHg and/or DBP ≥90 mmHg or known HT patients on antihypertensive medication irrespective of BP status [6]. Newly diagnosed HT patients were scheduled for extra visits to verify their BP statuses before treatment [30]. Confirmed HT patients received treatment according to existing national guidelines.

The initial screening for diabetes mellitus (DM) was based on measurement of random blood glucose (RGB) (HemoCue® 201 RT glucose analyzer (HemoCue AB, Angelholm, Sweden) and HbA1c (Afinion® AS 100 analyzer (Axis Shield PoC, AS, Oslo, Norway) levels. All women with RBG ≥11.1 mmol/l were scheduled for a fasting blood glucose (FBG) test [31]. DM was defined as FBG ≥7.0 mmol/l or RBG ≥11.1 mmol/l on at least two occasions (all plasma-equivalent), and/or HbA1c ≥48 mmol/mol (6.5%) or known DM patients on antidiabetic medication irrespective of glucose levels [31]. DM patients received treatment according to existing national guidelines. Haemoglobin levels (g/dl) were measured using Sysmex® KX-21N haematological analyzer (Sysmex Corporation Kobe, Japan). Anaemia was defined as Hb level <12 g/dl [32].

Ethical considerations

Ethical approval was obtained from the Medical Research Coordinating Committee (MRCC) of the National Institute for Medical Research in Tanzania (reference number NIMR/HQ/R.8a/Vol. IX/1717). Written informed consent was obtained from each woman before enrolment into the study in accordance with the Declaration of Helsinki [33].

Statistical analyses

All data were checked for consistency, double entered and validated using Microsoft Office Access 2007 database (Microsoft Corporation, Redmond USA). All analyses were performed using STATA version 13. (StataCorp, Lake Way Drive College Station, USA) software. Continuous variables were tested for normality using histograms and described using the mean and standard deviation if normally distributed or the median and interquartile range (IQR) for skewed data. Categorical variables were described using frequencies and percentages. Differences in parametric continuous variables among the normotensive, pre-HT, and HT groups were tested using analysis of variance (ANOVA) adjusted using the Bonferroni test for multiple comparisons, whereas Kruskal–Wallis tests was used to determine the association of non-parametric continuous risk factors across BP groups (normotensive, pre-HT and HT). The Chi square or Fisher's exact tests were used to compare categorical variables.

The primary outcome measure was BP evaluated as dichotomous i.e. HT (yes/no) or pre-HT (yes/no). For the analysis of prevalence of HT, we applied age-specific rates of HT and pre-HT to the WHO standard population [34] to generate age-standardised population prevalence estimates. The multivariate analysis of potential risk factors of pre-HT and/or HT was carried out by using logistic regression and presented as unadjusted and adjusted odds ratios (AOR) and respective 95% confidence intervals (CI). The logistic regression analyses followed a conceptual hierarchical model for controlling confounding variables [35]. The factors were categorised as distal (women age, marital status, education level and occupation), intermediate (smoking, alcohol consumption parity and previous use of hormonal contraceptives). Proximal factors included (biological factors (obesity and high haemoglobin levels, cardio metabolic conditions (DM and family history of HT or CVDs and hypertension during previous pregnancy. In the initial stage of multivariate logistic regression analysis model, all distal factors (block 1) with $P < 0.2$ [36] in the univariate analysis were adjusted for one another and retained if associated with pre-HT or HT at $P < 0.1$ [35]. This subset of variables was then adjusted with intermediate factors (block 2) using a similar approach and retained if $P < 0.1$. Finally, proximal factors (block 3) with $P < 0.2$ in univariate analysis were subsequently added and adjusted for one another until factors with $P < 0.1$ were

retained in the final model. A *P*-value <0.05 was considered statistically significant. Because of the high co-linearity between BMI, WC WHR, and core obesity, these measurements were not considered as independent variables in the same regression model having pre-HT or HT as the endpoint. Instead, four separate models were generated and the adjusted OR for each obesity measure compared. Receiver operating characteristic (ROC) curves were also generated in order to evaluate the abilities of these anthropometric indices to identify pre-HT and HT. The ability of each anthropometric index was shown as areas under the ROC curves and the 95% CIs.

Results

From July 2014 to December 2015, 2629 women were screened for eligibility for inclusion into the FOETALforNCD pre-pregnancy cohort of whom 1415 were enrolled (Figure 1). Of these, 1247 had BP measured, venous blood taken, and were confirmed not to be pregnant at the time of enrolment. 456 (36.6%) had pre-hypertension and 98 (7.9%) had HT (Figure 1). The prevalence rates increased slightly when standardised to the WHO world population (37.5% for pre-HT and 8.5% for HT (Table 1). Only 20/98 (20.2%) of HT patients were aware of their condition, and only eight were taking anti-HT medications of whom six had their BP adequately controlled (Figure 2). Of 78 newly diagnosed HT patients, 64 (82.1%) returned for the repeat BP measurements of whom 27/64 (42.2%) had their BP reverted to normal or pre-HT status without medication.

Table 1 shows the baseline socio-demographic characteristics, anthropometrics as well as distribution of normotensive, pre-HT and HT. The overall median age (IQR) was 28.3 (22.0–34.5) years, 56.6% were between the ages of 18–29 years. Most women were subsistence farmers (n = 712, 57.1%) with primary education (n = 786, 63.1%). Fifty-six (4.5%) drank alcohol and only two were smokers, 10 (0.8%) had DM and 458 (36.7%) had anaemia (Table 1).

HT women were significantly older (median age 33.0 years, IQR 22.7–37.0) than normotensive and

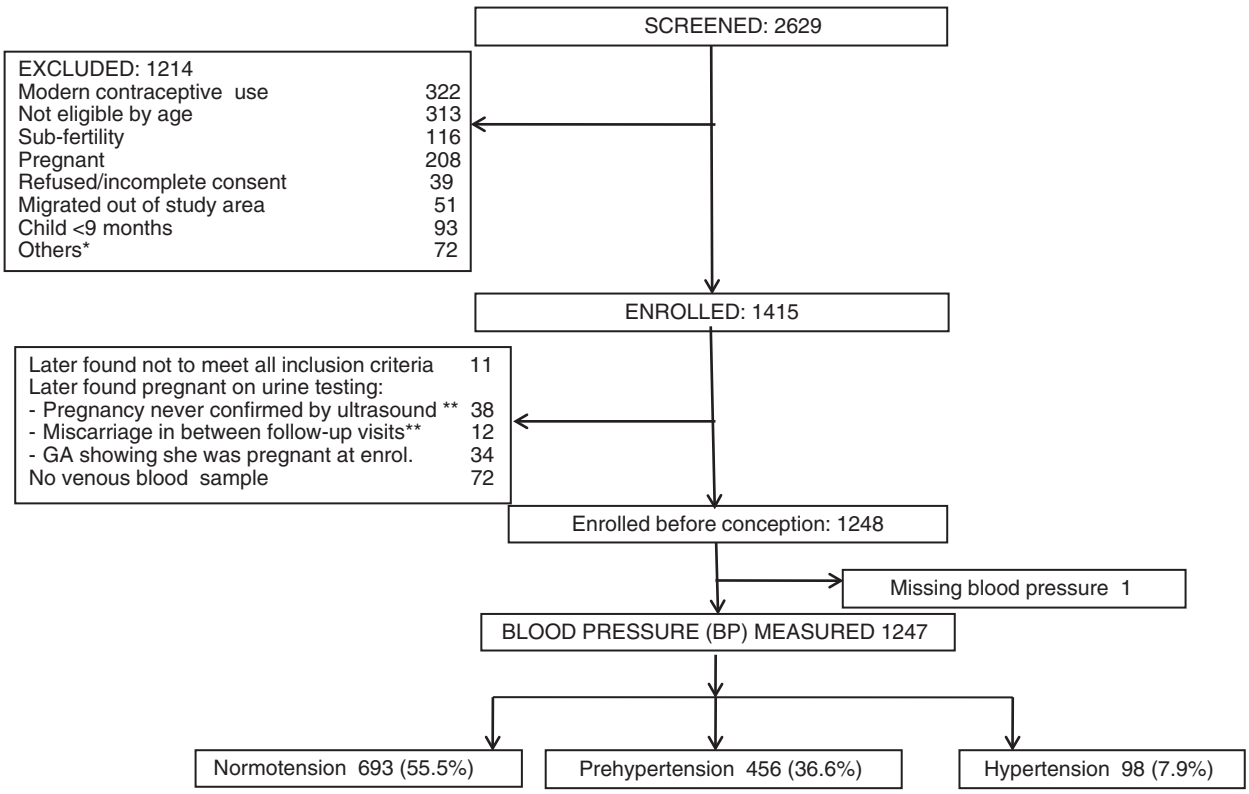

Figure 1 Flowchart for enrolment of the FOETALforNCD pre-pregnancy cohort. *Others include need to consult husband first, might move out of study area. ** women with unknown gestational age were excluded since it could not be known for sure if they were truly non-pregnant at the time of enrolment.

Table 1 Characteristics of non pregnant women of reproductive age by blood pressure categories

Characteristics	Total (*n*)	Normotensive *n* (%)/median (IQR)/mean ± SD	Prehypertensive *n* (%)/median (IQR)/mean ± SD	Hypertensive *n* (%)/median (IQR)/mean ±S D	*P* value
Age (years)[a]	1232	27.0 (21.0–33.0)	29.0 (23.0–35.0)	33.0 (22.7–37.0)	<0.001
18–24		273 (64.1)	141 (33.1)	12 (2.8)	
25–29		158 (58.3)	91 (33.6)	20 (8.1)	
30–34		117 (51.5)	90 (39.7)	22 (8.8)	
35–40		136 (41.2)	129 (41.2)	43 (14.0)	<0.001
Marital status	1244				
Never married		190 (62.9)	104 (34.4)	8 (2.7)	0.003
Married		421 (52.0)	313 (38.6)	76 (9.4)	
Separated		29 (59.2)	15 (30.6)	5 (10.2)	
Divorced		44 (62.9)	19 (27.1)	7 (10.0)	
Education level	1244				
Secondary or higher		142 (64.8)	68 (31.1)	9 (4.1)	0.032
Primary completed		424 (53.9)	299 (38.0)	63 (8.0)	
Primary incomplete		73 (52.1)	50 (35.7)	17 (12.4)	
None		54 (53.5)	38 (37.9)	9 (8.9)	
Occupation	1246				
Professional		24 (63.2)	12 (31.6)	2 (5.3)	0.078
Business		113 (59.5)	58 (30.5)	19 (10.0)	
Service		27 (62.8)	13 (30.2)	3 (7.0)	
Farmer		370 (52.0)	280 (39.3)	62 (8.7)	
Housewife/students		159 (60.4)	92 (35.0)	12 (4.6)	
Alcohol consumption	1244				
Yes		30 (53.6)	22 (39.3)	4 (7.1)	0.90
No		662 (55.7)	432 (36.4)	94 (7.9)	
Parity	1241				
<2		303 (62.2)	166 (34.1)	18 (3.7)	<0.001
≥2		390 (51.7)	287 (38.1)	77 (10.2)	
BMI categories (kg/m$^{2)}$†	1230	21.9 (20.0–24.9)	23.9 (21.2–27.4)	24.0 (21.2–28.5)	<0.001
Underweight		69 (69.7)	26 (26.3)	4 (4.0)	
Normal weight		451 (60.5)	242 (32.5)	58 (7.0)	
Overweight		118 (47.6)	112 (45.2)	18 (7.3)	
Obesity		45 (32.6)	71 (51.5)	22 (15.9)	
Waist circumference (cm)	1217	78.5 (73.0–85.3)	82.3 (75.8–90.5)	84.3 (77.2–93.5)	<0.001
Abdominal obesity	1217				
Yes		292 (46.9)	270 (43.3)	61 (9.8)	<0.001
No		380 (64.0)	179 (30.1)	35 (5.9)	
Waist to hip ratio (WHR)	1208	0.85 (0.81–0.88)	0.86 (0.82–0.89)	0.88 (0.84–0.91)	<0.001
High (≥0.85)		314 (49.4)	256 (40.3)	66 (10.4)	<0.001
Normal (<0.85)		353 (61.7)	189 (33.0)	30 (5.2)	
Core obesity§	1187				
Yes		42 (33.9)	63 (50.8)	19 (15.3)	<0.001
No		618 (58.1)	371 (34.9)	74 (7.0)	
Haemoglobin level (mmol/l)‡	1247	12.1 ± 1.5	12.4 ± 1.5	12.5 ± 1.6	0.001
Anaemia	1247				
Yes		278 (60.7)	149 (32.5)	31 (8.8)	0.021
No		415 (52.6)	307 (38.9)	67 (8.5)	
Diabetes mellitus	1247				
Yes		3 (30)	4 (40)	3 (30)	0.023
No		690 (57.8)	452 (36.5)	95 (7.7)	
Family history of CVDs or DM	1247				
Yes		221 (58.8)	126 (33.5)	29 (7.7)	0.304
No		472 (54.2)	330 (37.9)	69 (7.9)	

Table 1 (*Continued*)

Characteristics	Total (*n*)	Normotensive *n* (%)/median (IQR)/mean ± SD	Prehypertensive *n* (%)/median (IQR)/mean ± SD	Hypertensive *n* (%)/median (IQR)/mean ±S D	*P* value
Had hypertension during previous pregnancy	1017				
Yes		19 (43.2)	18 (40.9)	7 (15.9)	0.190
No		523 (55.8)	364 (37.4)	89 (8.8)	
Systolic blood pressure (mmHg)	1247	109 ± 6.2	123.8 ± 5.9	139 ± 17.5	<0.001
Diastolic blood pressure	1247	69.9 ± 5.4	79.8 ± 5.3	93.7 ± 10.8	<0.001
Age standardised preHT and HT prevalence	1230	-	457 (37.2)	105 (8.5)	

CVDs, cardiovascular diseases; DM, diabetes mellitus; HT, hypertension; preHT, pre-hypertension. Classification of Blood pressure—Normal: SBP <120 mm Hg and DBP <80 mm Hg; pre-hypertension: SBP 120–139 mm Hg and/or DBP 80–89 mm Hg; hypertension: SBP ≥140 mmHg and/or DBP ≥90 mmHg greater, or known HT patients on antihypertensive medication irrespective of BP status.
†Median (IQR).
‡Mean±SD.
§The abdominal obesity defined as WC ≥80 cm and core obesity defined as coexistence of obesity by BMI, WHR and WC in the same person.

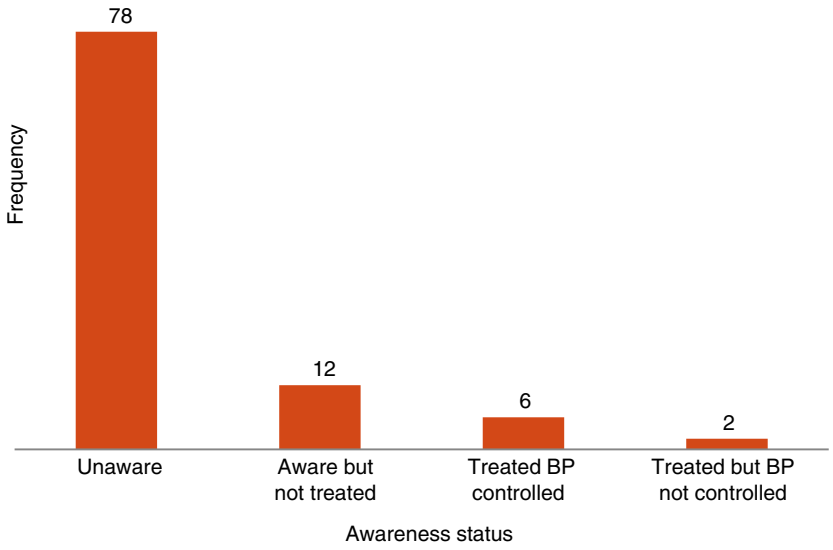

Figure 2 Awareness, treatment and control among women with hypertension in Korogwe, Tanzania (*n* = 98). [Colour figure can be viewed at wileyonlinelibrary.com].

pre-HT individuals. Women who engaged in subsistence farming or small-scale business or completed primary school had a significantly higher prevalence of pre-HT and HT. The medians (IQR) of BMI, WC, WHR were 22.7 (20.4–26.3), 80.0 (74–87.1), 0.85 (0.82–0.89), respectively. The three measurements appear to provide different prevalences of obesity, with generalised obesity (BMI) being lowest (11.2%) followed by WC (51.2%) while WHR yielded the highest prevalence of obesity (52.7%). Among the obese women, 111/1195 (9.2%) had core obesity. There was a trend of increased proportions of both pre-HT and HT with increasing BMI, WC and WHR (Table 1).

Tables 2 and 3 show the unadjusted and adjusted logistic regression analyses of the factors associated with pre-HT and HT. In adjusted analyses, women aged 35–40 had greater odds of pre-HT than women who were 18–24 years old (Table 2). Similarly, women aged 25–29,

Table 2 Risk factors of pre-hypertension among non-pregnant women of reproductive age in Korogwe, Tanzania (n = 1141)

Characteristics	Unadjusted OR (95% CI)	Adjusted OR (95% CI)			
		Model 1	Model 2	Model 3	Model 4
Age (years)					
18–24	Reference	Reference	Reference	Reference	Reference
25–29	1.12 (0.80–1.55)	0.99 (0.70–1.40)	0.99 (0.70–1.38)	1.07 (0.76–1.49)	1.06 (0.74–1.50)
30–34	1.49 (1.06–2.10)	1.38 (0.97–1.97)	1.34 (0.94–1.91)	1.41 (0.99–2.01)	1.44 (0.98–2.10)
35–40	1.84 (1.34–2.52)	**1.72 (1.24–2.39)**	**1.62 (1.16–2.6)**	**1.71 (1.23–2.39)**	**1.76 (1.23–2.03)**
Marital status					
Never married	Reference	Reference	Reference	Reference	Reference
Married	1.36 (1.02–1.80)	1.02 (0.74–1.40)	1.07 (0.78–1.47)	1.06 (0.77–1.45)	1.03 (0.75–1.42)
Separated	0.94 (0.48–1.84)	0.72 (0.35–1.45)	0.73 (0.36–1.48)	0.74 (0.37–1.50)	0.78 (0.39–1.59)
Divorced	0.79 (0.44–1.42)	0.64 (0.34–1.19)	0.61 (0.32–1.16)	0.60 (0.32–1.13)	0.57 (0.30–1.08)
Widowed	1.04 (0.30–3.65)	0.81 (0.21–3.06)	1.23 (0.31–4.86)	1.09 (0.28–4.25)	0.81 (0.22–3.04)
Education level					
Secondary or higher	Reference	Reference	Reference	Reference	Reference
Primary completed	1.47 (0.89–2.44)	1.27 (0.73–2.19)	1.27 (0.73–2.19)	1.27 (0.73–2.19)	1.27 (0.73–2.19)
Primary incomplete	1.43 (0.90–2.27)	1.14 (0.69–1.89)	1.14 (0.69–1.89)	1.14 (0.69–1.89)	1.14 (0.69–1.89)
None	1.47 (0.89–2.44)	1.25(0.87–1.78)	1.25 (0.87–1.78)	1.25 (0.87–1.78)	1.25 (0.87–1.78)
Occupation					
Housewife	Reference	Reference	Reference	Reference	Reference
Farmer	1.31 (0.41–1.77)	1.00 (0.71–1.76)	1.00 (0.71–1.76)	1.00 (0.71–1.76)	1.00 (0.71–1.76)
Business	0.83 (0.41–1.33)	0.79 (0.39–1.62)	0.79 (0.39–1.62)	0.79 (0.39–1.62)	0.79 (0.39–1.62)
Service	0.89 (0.59–1.69)	0.80 (0.59–1.23)	0.80 (0.59–1.23)	0.80 (0.59–1.23)	0.80 (0.59–1.23)
Professional	0.86 (0.97–1.81)	0.83 (0.38–1.82)	0.83 (0.38–1.82)	0.83 (0.38–1.82)	0.83 (0.38–1.82)
Parity					
<2	Reference	Reference	Reference	Reference	Reference
≥2	1.34 (1.05–1.71)	0.92 (0.64–1.31)	0.92 (0.64–1.31)	0.92 (0.64–1.31)	0.92 (0.64–1.31)
Family history of CVDs or DM	0.82 (0.63–1.06)	0.83 (0.63–1.09)	0.86 (0.65–1.13)	0.86 (0.66–1.13)	0.85 (0.66–1.12)
Body mass index (kg/m^2)					
Underweight	0.70 (0.44–1.13)	0.71 (0.44–1.16)	–	–	–
Normal weight	Reference	Reference	–	–	–
Overweight	1.77 (1.31–2.39)	**1.67 (1.22–2.28)**	–	–	–
Obesity	3.13 (2.10–4.41)	**2.55 (1.68–3.87)**	–	–	–
Abdominal obesity	2.94 (1.96–2.74)	–	**1.80 (1.20–2.32)**	**–**	**–**
High waist to hip ratio	1.61 (1.26–2.04)	–	**–**	**1.37 (1.06–1.76)**	**–**
Core obesity†	2.50 (1.66–3.77)	–	**–**		**2.16 (1.41–3.30)**
Haemoglobin level (g/dl)	1.15(1.06–1.25)	**1.14 (1.04–1.24)**	**1.16 (1.06–1.26)**	**1.17 (1.08–1.27)**	**1.16 (1.06–1.26)**

CVDs; Cardiovascular disease.

†Core obesity defined as coexistence of obesity by BMI, WHR and WC in the same person. Four different models were generated and compared to identify the strength of associations between obesity by BMI (model 1, pseudo R^2 = 0.12), Waist circumference (model 2, pseudo R^2 = 0.04), Waist to hip ratio (model 3 pseudo R^2 = 0.03) and core obesity (model 4 pseudo R^2 = 0.03) and risk of pre-HT. The initial models included all variables with $P < 0.20$ in the univariate analyses. The final multivariate models included all variables with $P < 0.1$ (age, marital status, body mass index, abdominal obesity, high waist to hip ratio and core obesity, and haemoglobin level). A hierarchical approach was used in the analyses. The OR (95% CI) shown for education level, occupation, parity, and family history of CVDs were the values obtained just before they were removed from the model, due to a $P > 0.10$.

The bold parameters are the variables that were statistically significant ($P < 0.05$) in multivariate analysis.

30–34, and 35–40 years had greater odds of HT than those aged 18–24 years old (Table 3). For anthropometric measurements, the odds of pre-HT and HT were approximately three times as high for generalised obesity (BMI) after adjusting for other factors. Obesity by WC was significantly associated with an increased risk of pre-HT but marginally associated with HT after adjusting for other factors while WHR was significantly associated with both pre-HT and HT. The odds of pre-HT and HT for obesity by all three indices (core obesity) were comparable to when high BMI was used alone (model 4), but much higher compared to when WC or WHR were used alone (Table 3). Finally, increasing Hb levels were associated with increased risk of both pre-HT and HT. The

Table 3 Risk factors of hypertension among non pregnant, fecund women of reproductive age in Korogwe, Tanzania

Characteristics	Unadjusted OR (95% CI)	Adjusted OR (95% CI)			
		Model 1	Model 2	Model 3	Model 4
Age (years)					
18–24	Reference	Reference	Reference	Reference	
25–29	3.17 (1.53–6.57)	**2.59 (1.23–5.47)**	**2.22 (1.03–4.77)**	**2.54 (1.20–5.37)**	**2.72 (1.30–5.75)**
30–34	3.89 (1.84–8.21)	**2.84 (1.29–6.27)**	**2.50 (1.11–5.62)**	**3.20 (1.48–6.91)**	**2.77 (1.25–6.12)**
35–40	7.19 (1.67–14.09)	**6.79 (3.38–13.64)**	**5.26 (2.49–1.10)**	**6.43 (3.19–12.95)**	**6.74 (3.35–13.55)**
Marital status					
Never married	Reference	Reference	Reference	Reference	
Married	4.29 (2.03–9.06)	2.05 (0.90–4.65)	2.00 (0.88–4.52)	1.79 (0.79–4.07)	1.98 (0.87–4.51)
Separated	4.09 (1.25–13.38))	2.08 (0.59–7.38)	1.55 (0.41–5.83)	1.40 (0.37–5.31)	2.06 (0.58–7.36)
Divorced	3.78 (1.30–10.97)	2.07 (0.65–6.57)	1.86 (0.59–5.85)	1.74 (0.55–5.51)	1.75 (0.55–5.55)
Widowed	6.79 (1.21–38.02)	2.03 (0.30–13.46)	3.39 (0.50–22.90)	2.65 (0.40–17.60)	2.00 (0.30–13.28)
Education level					
None	Reference	Reference	Reference	Reference	Reference
Primary incomplete	2.63 (0.99–6.98)	1.12 (0.40–3.20)	1.12 (0.40–3.20)	1.12 (0.40–3.20)	1.12 (0.40–3.20)
Primary completed	3.67 (1.56–8.65)	1.51 (0.59–3.86)	1.51 (0.59–3.86)	1.51 (0.59–3.86)	1.51 (0.59–3.86)
Secondary or higher	2.34 (1.14–4.83)	1.12 (0.51–2.46)	1.12 (0.51–2.46)	1.12 (0.51–2.46)	1.12 (0.51–2.46)
Occupation					
Housewife	Reference				
Farmer	2.2 2(1.16–4.23)	0.98 (0.48–1.99)	0.98 (0.48–1.99)	0.98 (0.48–1.99)	0.98 (0.48–1.99)
Service	1.47 (0.39–5.56)	1.31 (0.36–5.79)	1.31 (0.36–5.79)	1.31 (0.36–5.79)	1.31 (0.36–5.79)
Business	2.22 (1.04– 4.77)	1.43 (0.59–2.94)	1.43 (0.59–2.94)	1.43 (0.59–2.94)	1.43 (0.59–2.94)
Professional	1.10 (0.23–5.24)	0.66 (0.12–1.99)	0.66 (0.12–1.99)	0.66 (0.12–1.99)	0.66 (0.12–1.99)
Parity					
<2	Reference	Reference	Reference	Reference	
≥2	3.32 (1.95–5.67)	1.22 (0.61–2.44)	1.22 (0.61–2.44)	1.22 (0.61–2.44)	1.22 (0.61–2.44)
Had hypertension during previous pregnancy	2.69 (1.10–6.57)	2.59 (0.98–6.82)	2.36 (0.91–6.14)	2.55 (0.98–6.61)	2.64 (0.96–7.21)
Previous use of hormonal contraceptives	2.67 (1.10–6.57)	1.12 (0.61–2.04)	1.12 (0.61–2.04)	1.12 (0.61–2.04)	1.12 (0.61–2.04)
Body mass index (kg/m^2)					
Underweight	0.50 (0.18–1.43)	0.57 (0.20–1.67)	–	–	–
Normal weight	Reference	Reference	Reference	–	–
Overweight	1.32 (0.75–2.35)	1.08 (0.59–1.97)	–	–	–
Obesity	4.24 (2.36–7.61)	**2.92 (1.57–5.44)**	–	–	–
Abdominal obesity	2.35 (1.48–3.73)		1.60 (0.99–2.57)	–	–
High waist to hip ratio	2.47 (1.57–3.91)		–	**1.89 (1.17–3.07)**	
Core obesity†	3.78 (2.09–6.84)	–	–		**2.80 (1.50–5.25)**
Haemoglobin level (g/dl)	1.26 (1.07–1.47)	**1.33 (1.12–1.58)**	**1.28 (1.08–1.61)**	**1.32 (1.17–1.57)**	**1.33 (1.12–1.58)**
Diabetes mellitus	7.26 (1.45–36.50)	3.26 (0.55–19.32)	3.74 (0.67–20.86)	4.61 (0.86–24.83)	2.89 (0.44–19.13)

†Core obesity defined as coexistence of obesity by BMI, WHR and WC in the same person. Four different models were generated and compared to identify the strength of associations between obesity by BMI (model 1, pseudo $R^2 = 0.12$), Waist circumference (model 2, pseudo $R^2 = 0.11$), Waist to hip ratio (model 3 pseudo $R^2 = 0.11$) and core obesity (model 4 pseudo $R^2 = 0.11$) and the risk of HT. The initial models included all variables with $P < 0.20$ in the univariate analyses. The final multivariate models included all variables with $P < 0.1$ (age, marital status, body mass index, abdominal obesity, high waist to hip ratio and core obesity, and haemoglobin level). A hierarchical approach was used in this analys. The OR (95%CI) shown for education level, occupation, parity, previous use of hormonal contraceptives, and hypertension during previous pregnancy and diabetes mellitus were the value obtained just they were removed from the model, due to $P > 0.10$.
The bold parameters are the variables that were statistically significant ($P < 0.05$) in multivariate analysis.

associations between marital status, education levels and high parity were no longer statistical significantly associated with pre-HT and HT after adjusting for other factors (Tables 2 and 3). Furthermore, previous use of hormonal contraceptives, hypertension during previous pregnancy and DM were no longer associated with increased risk of HT after adjusting for other factors (Table 3).

In the ROC analyses the area under curve (AUC) for BMI, WHR, WC, and core obesity for identifying women with pre-HT were 0.63 (95% CI 0.59–0.66), 0.57 (95% CI 0.53–0.60), 0.60 (95% CI 0.57–0.64) and 0.54 (95% CI 0.52–0.56) (Figure 3a). For HT, the AUC for BMI, WHR, WC and core obesity were 0.63 (95% CI 0.57–0.69), 0.67 (95% CI 0.57–0.73), 0.66 (95% CI 0.60–0.72) and 0.56 (95% CI 0.52–0.60), respectively (Figure 3b). The ability to identify pre-HT individuals based on obesity was slightly higher for BMI than WHR and WC. For hypertension, WHR and WC performed better than BMI. Core obesity had the lowest AUC. However, there was no statistically significant difference between the observed AUC for the four obesity measures (Figure 3).

Discussion

In the present study, we assessed the risk factors of pre-HT and HT among non-pregnant women of reproductive age (18–40 years) in a rural setting of northeastern Tanzania. Pre-HT was very common among women of reproductive age in this rural setting. Other studies elsewhere in LMICs have demonstrated a great variation in the burden of pre-HT and HT among women of reproductive age [9–11, 37]. For instance, the age standardised prevalence of pre-HT observed in our study (37.2%) is comparable to 41.3% among women aged 18–49 years in rural Ethiopia [9], but much higher compared to 14.4% in rural Nepal [37].

The prevalence of HT in our study as well as others that involved women of reproductive age [8, 10, 37] was low. The low burden of HT among women of reproductive age could be attributed to young age of participants included in these studies. In this study, we defined HT as based on BP measured at enrolment. Clinical criteria for the diagnosis of HT recommends two measurements taken at different occasions [30]. This was clearly demonstrated in our study since 42.2% of newly diagnosed HT who returned for the follow-up visits had their BP reverted to <140/90 mmHg.

Despite low prevalence of HT, the high burden of pre-HT in this study is alarming since a number of observational studies have shown that without appropriate interventions, many pre-HT individuals will progress to overt HT as they grow older [12–14]. Zambarana *et al.* [14] reported that 30.4% of pre-HT postmenopausal women in the USA progressed to HT as compared to only 9% of normotensive women after 3 years. Another study by Ishikawa *et al.* [13] reported that among normotensive

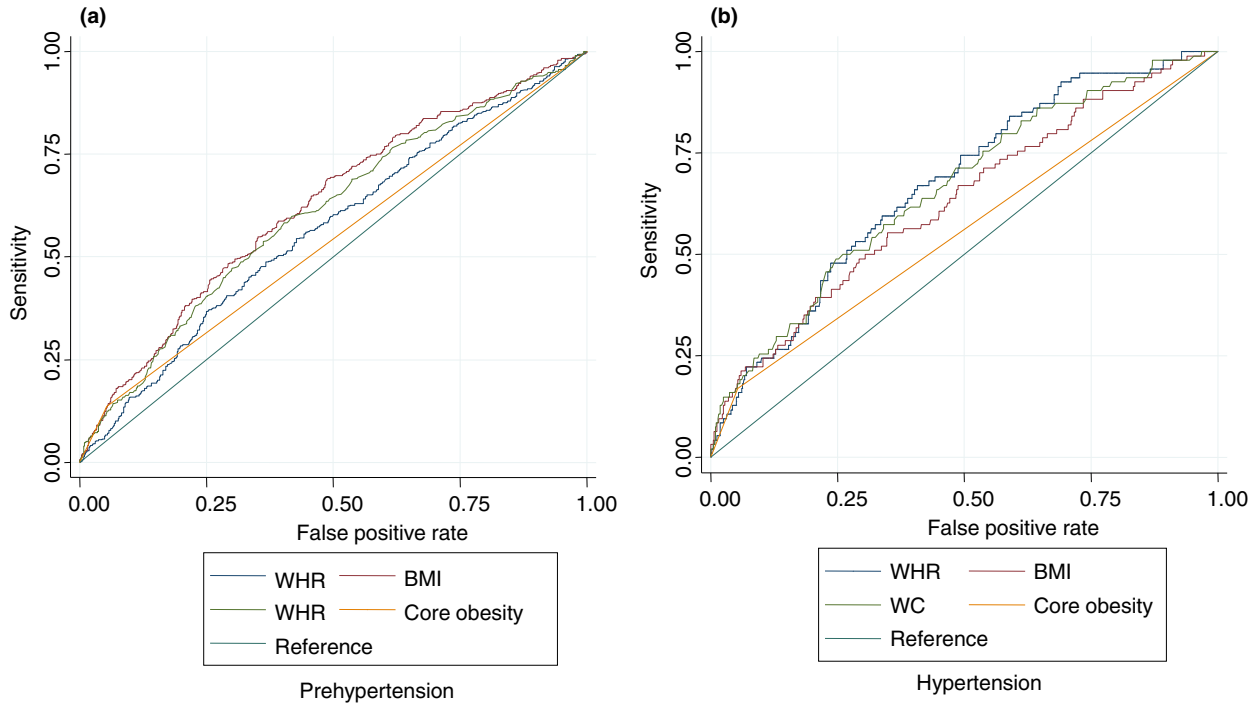

Figure 3 ROC curves of BMI, WHR, WC and core obesity for prediction of pre-hypertension and hypertension among non-pregnant women in Korogwe, Tanzania. [Colour figure can be viewed at wileyonlinelibrary.com].

individuals at baseline (n = 702), 34.1% and 6.6% progressed to pre-HT and HT, respectively, while 26.1% of pre-HT at baseline progressed to HT (median follow-up period 11.8 years).

The influence of pre-HT on birth outcomes in SSA is not clear but recent reports from higher income countries have reported that pre-HT early in pregnancy was associated with an increased risk of small for gestation age, pregnancy induced hypertension, neonatal sepsis and perinatal mortality [38, 39]. Therefore, without appropriate intervention, over one third of women in our study could potentially be at risk of adverse pregnancy outcomes. Future analysis involving women who became pregnant in the FOETALforNCD study will shed some light on the influence of pre-HT at different time points on pregnancy outcomes.

Similar to other studies [3, 4, 14, 40], our age standardised -specific prevalence estimates show that the risk of HT in developing countries is evident even in young women; therefore interventions early in the life course will be essential. Furthermore, the majority of HT patients were not aware of their condition and less than half of known patients were taking medication. Low awareness of HT in our study warrants for concerted efforts to improve the detection and treatment of HT for this vulnerable group of women. Routine BP measurements patients while seeking other health care services have been shown to improve the identification of many previously undiagnosed cases of HT and pre-HT in Tanzania [8].

Anthropometric measurements are cheap and simple tools for detection of overweight and obesity, major risk factors of CVDs, but there is a growing debate on the utility of different measures of obesity in predicting the risk of CVDs in Africa [41, 42]. However, for better diagnosis of obesity, it is recommended that BMI values are combined with other measures of adiposity such as WC or WHR, in individual and collective assessments [43]. Our study shows that the prevalence of obesity varied considerably according to the anthropometric index used being lowest by BMI and core obesity and highest for WC and WHR. However, obesity by BMI was more strongly associated with an increased risk of pre-HT and HT as compared to WHR or WC alone. On the other hand, ROC analyses showed that the ability of BMI in identifying HT patients was lower compared to WC or WHR, but the observed difference was not statistically significant. This could be attributed to the young age of our cohort as compared to other studies [42, 44].

Similar to other studies [20, 24, 25, 32], risk of pre-HT and HT increased with increasing Hb levels. The biological mechanisms that explain the link between high Hb level and high BP are unclear, but increased blood viscosity, activation of renin-angiotensin-aldosterone system and variation in erythropoietin secretion have all previously been suggested [22].

The current study has several strengths. Firstly, stringent inclusion criteria were used to identify women who were likely to conceive. This valuable data and gives an opportunity for design of preconception care interventions including timely diagnosis and management HT by targeting women who are at increased risk of unwanted or mistimed pregnancies. Secondly, great care was taken to ensure that only non-pregnant women were included in the analysis, based on repeated pregnancy tests and ultrasound-based estimation of gestational age.

However, our study also had some limitations. Firstly, women who were using modern contraceptive methods except for condoms or those with babies aged less than 9 months were excluded from this study. The two groups of women might differ considerably in socioeconomic or demographic and anthropometric characteristics. Secondly, pre-HT women who did not conceive during the study period were not followed up with repeated BP measurements and hence their long-term BP status could not be ascertained. Future studies that could follow the established cohort and assess the progression to HT from the pre-HT cases are hereby warranted. Finally, other risk factors such as dietary pattern, physical inactivity and blood lipid profiles that could possibly be associated with HT were not evaluated.

Conclusion

This study shows that a large number of rural women of reproductive age have pre-HT, whereas the prevalence of HT was relatively low. High prevalence of pre-HT poses a great challenge ahead, as most women may progress towards HT as they grow older. Overweight and obesity were prevalent in this study and the single most significant modifiable risk factor for both pre-HT and HT.

Acknowledgements

We thank all women who participated in this study, community leaders, KDH, NIMR Korogwe Research Laboratory staff and Danish Council for Strategic Research, which funded the FOETALforNCD study.

References

1. Schutte AE, Botha S, Fourie CMT *et al.* Recent advances in understanding hypertension development in sub-Saharan Africa. *J Hum Hypertens* 2017: **31**: 491–500.

2. Modesti PA, Agostoni P, Agyemang C *et al.* Cardiovascular risk assessment in low-resource settings: a consensus document of the European Society of Hypertension Working Group on Hypertension and Cardiovascular Risk in Low Resource Settings. *J Hypertens* 2014: **32**: 951–960.
3. Hendriks ME, Wit FW, Roos MT *et al.* Hypertension in sub-Saharan Africa: cross-sectional surveys in four rural and urban communities. *PLoS ONE* 2012: **7**: e32638.
4. de Ramirez SS, Enquobahrie DA, Nyadzi G *et al.* Prevalence and correlates of hypertension: a cross-sectional study among rural populations in sub-Saharan Africa. *J Hum Hypertens* 2010: **24**: 786–795.
5. Forouzanfar MH, Liu P, Roth GA *et al.* Global burden of hypertension and systolic blood pressure of at least 110 to 115 mm Hg, 1990-2015. *JAMA* 2017: **317**: 165–182.
6. Chobanian AV, Bakris GL, Black HR *et al.* The seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. *JAMA* 2003: **289**: 2560–2572.
7. Guwatudde D, Nankya-Mutyoba J, Kalyesubula R *et al.* The burden of hypertension in sub-Saharan Africa: a four-country cross sectional study. *BMC Public Health* 2015: **15**: 1211.
8. Mosha NR, Mahande M, Juma A *et al.* Prevalence, awareness and factors associated with hypertension in North West Tanzania. *Glob Health Action* 2017: **10**: 1321279.
9. Mengistu MD. Pattern of blood pressure distribution and prevalence of hypertension and prehypertension among adults in Northern Ethiopia: disclosing the hidden burden. *BMC Cardiovasc Disord* 2014: **14**: 33.
10. Chowa PE, Lin C, Goma F, South-Paul J. Prevalence of hypertension among women of child bearing age in Zambia. *Med J Zambia* 2011: **38**: 3–8.
11. Larson E, Rabkin M, Mbaruku GM, Mbatia R, Kruk ME. Missed opportunities to improve the health of postpartum women: high rates of untreated hypertension in rural Tanzania. *Matern Child Health J* 2017: **21**: 407–413.
12. Hsia J, Margolis KL, Eaton CB *et al.* Prehypertension and cardiovascular disease risk in the Women's Health Initiative. *Circulation* 2007: **115**: 855–860.
13. Ishikawa Y, Ishikawa J, Ishikawa S, Kario K, Kajii E. Progression from prehypertension to hypertension and risk of cardiovascular disease. *J Epidemiol* 2017: **27**: 8–13.
14. Zambrana RE, Lopez L, Dinwiddie GY *et al.* Prevalence and incident prehypertension and hypertension in postmenopausal Hispanic women: results from the Women's Health Initiative. *Am J Hypertens* 2014: **27**: 372–381.
15. Magnussen EB, Vatten LJ, Lund-Nilsen TI, Salvesen K, Smith GD, Romundstad PR. Prepregnancy cardiovascular risk factors as predictors of pre-eclampsia: population based cohort study. *BMJ* 2007: **335**: 978–978.
16. Panaitescu AM, Syngelaki A, Prodan N, Akolekar R, Nicolaides KH. Chronic hypertension and adverse pregnancy outcomes: a cohort study. *Ultrasound Obstet Gynecol* 2017: **50**: 228–235.
17. Sibai BM, Lindheimer M, Hauth J *et al.* Risk factors for preeclampsia, abruptio placentae, and adverse neonatal outcomes among women with chronic hypertension. *N Engl J Med* 1998: **339**: 667–671.
18. Nobles CJ, Mendola P, Mumford SL *et al.* Preconception blood pressure levels and reproductive outcomes in a prospective cohort of women attempting pregnancy. *Hypertension* 2018: **71**: 904.
19. Chappell LC, Enye S, Seed P, Briley AL, Poston L, Shennan AH. Adverse perinatal outcomes and risk factors for preeclampsia in women with chronic hypertension: a prospective study. *Hypertension* 2008: **51**: 1002–1009.
20. Atsma F, Veldhuizen I, de Kort W, van Kraaij M, Pasker-de Jong P, Deinum J. Hemoglobin level is positively associated with blood pressure in a large cohort of healthy individuals. *Hypertension* 2012: **60**: 936–941.
21. Kawamoto R, Tabara Y, Kohara K *et al.* A slightly low hemoglobin level is beneficially associated with arterial stiffness in Japanese community-dwelling women. *Clin Exp Hypertens* 2012: **34**: 92–98.
22. Kawamoto R, Tabara Y, Kohara K *et al.* Hematological parameters are associated with metabolic syndrome in Japanese community-dwelling persons. *Endocrine* 2013: **43**: 334–341.
23. Kim MY, Jee SH, Yun JE, Baek SJ, Lee DC. Hemoglobin concentration and risk of cardiovascular disease in Korean men and women - The Korean Heart Study. *J Korean Med Sci* 2013: **28**: 1316–1322.
24. Kim NH, Lee JM, Kim HC *et al.* Cross-sectional and longitudinal association between hemoglobin concentration and hypertension: a population-based cohort study. *Medicine* 2016: **95**: e5041.
25. Mugisha JO, Baisley K, Asiki G, Seeley J, Kuper H. Prevalence, types, risk factors and clinical correlates of anaemia in older people in a rural Ugandan population. *PLoS ONE* 2013: **8**: e78394.
26. Rasmussen JB, Mwaniki DL, Kaduka LU *et al.* Hemoglobin levels and blood pressure are associated in rural black Africans. *Am J Hum Biol* 2016: **28**: 145–148.
27. Papageorghiou AT, Kennedy SH, Salomon LJ *et al.* International standards for early fetal size and pregnancy dating based on ultrasound measurement of crown-rump length in the first trimester of pregnancy. *Ultrasound Obstet Gynecol* 2014: **44**: 641–648.
28. Papageorghiou AT, Kemp B, Stones W *et al.* Ultrasound-based gestational-age estimation in late pregnancy. *Ultrasound Obstet Gynecol* 2016: **48**: 719–726.
29. de Onis M, Habicht JP. Anthropometric reference data for international use: recommendations from a World Health Organization Expert Committee. *Am J Clin Nutr* 1996: **64**: 650–658.
30. Mancia G, Fagard R, Narkiewicz K *et al.* ESH/ESC guidelines for the management of arterial hypertension: the Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). *Blood Press* 2013: **22**: 193–278.
31. American Diabetes Association. Diagnosis and Classification of Diabetes Mellitus. Diabetes Care 2014: **37**: S81–S90.

32. Nebeck K, Gelaye B, Lemma S *et al.* Hematological parameters and metabolic syndrome: findings from an occupational cohort in Ethiopia. *Diabetes Metab Syndr* 2012: **6**: 22–27.
33. Dixon JR. The international conference on harmonization good clinical practice guideline. *Quality Assurance* 1999: **6**: 65–74.
34. Ahmad OB, Boschi-Pinto C, Lopez AD, Murray CJ, Lozano R, Inoue M. Age standardization of rates: a new WHO standard.
35. Victora CG, Huttly SR, Fuchs SC, Olinto MT. The role of conceptual frameworks in epidemiological analysis: a hierarchical approach. *Int J Epidemiol* 1997: **26**: 224–227.
36. Altman DG. *Practical Statistics for Medical Research*. London: CRR Press., Chapman and Hall 1991; 349.
37. Khan RJ, Stewart CP, Christian P *et al.* A cross-sectional study of the prevalence and risk factors for hypertension in rural Nepali women. *BMC Public Health* 2013: **13**: 55.
38. Wikström AK, Gunnarsdottir J, Nelander M, Simic M, Stephansson O, Cnattingius S. Prehypertension in pregnancy and risks of small for gestational age infant and stillbirth. *Hypertension* 2016: **67**: 640–646.
39. Rosner JY, Gutierrez M, Dziadosz M *et al.* Prehypertension in Early Pregnancy: what is the Significance? *Am J Perinatol* 2017: **34**: 117–122.
40. Muchanga M, Lepira FB, Tozin R *et al.* Prevalence and risk factors of pre-hypertension in Congolese pre and post menopausal women. *Afr Health Sci* 2016: **16**: 979–985.
41. Bouguerra R, Alberti H, Smida H *et al.* Waist circumference cut-off points for identification of abdominal obesity among the Tunisian adult population. *Diabetes Obes Metab* 2007: **9**: 859–868.
42. Ekoru K, Murphy GAV, Young EH *et al.* Deriving an optimal threshold of waist circumference for detecting cardiometabolic risk in sub-Saharan Africa. *Int J Obes* 2018: **42**: 487.
43. World Health Organization Obesity: preventing and managing the global epidemic: report of a WHO Consultation on Obesity, Geneva, 3–5 June 1997. (Available from http://apps.who.int/iris/bitstream/handle/10665/63854/WHO_NUT_NCD_98.1_%28p159-276%29.pdf?sequence=2&isAllowed=y1998). [25 August 2018]
44. Lam BCC, Koh GCH, Chen C, Wong MTK, Fallows SJ. Comparison of Body Mass Index (BMI), Body Adiposity Index (BAI), Waist Circumference (WC), Waist-To-Hip Ratio (WHR) and Waist-To-Height Ratio (WHtR) as Predictors of Cardiovascular Disease Risk Factors in an Adult Population in Singapore. *PLoS ONE* 2015: **10**: e0122985.

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