ISSN: 2832-7705

Research Article

International Journal of Clinical and Medical Education Research

Association between Anthropometric indices and Cardiometabolic Risk Factors among Women with Primary Infertility

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Submitted: 27 Jun 2022; **Accepted**: 08 Jul 2022; **Published**: 01 Aug 2022

Citation: *Antwi. EO., Baah. V. (2022). Association between Anthropometric indices and Cardiometabolic Risk Factors among Women with Primary Infertility. Int J Clin Med Edu Res. 1(2), 54-63.*

Abstract

Background: *Cardiometabolic risk factors are commonly associated with women with infertility. The study evaluated the association between anthropometric indices and cardiometabolic risk factors in women with primary infertility.*

Methods: *Two-hundred and sixteen (216) women with primary infertility underwent simple anthropometric measurement including waist circumference (WC), waist-to-height ratio (WHtR), body mass index (BMI), body adiposity index (BAI) and abdominal volume index (AVI). Blood pressure was assessed using an automated BP monitor and fasting blood samples were collected. Cardiometabolic risk factors were de ned according to the NCEPATP III criteria. Receiver Operating Characteristic (ROC) curve and logistic regression analyses were used to evaluate associations.*

Results: *The mean age of the study participants was 30.3 years and the median duration of infertility was 3.0 (2.0-4.0 interquartile range). The prevalence of hypertension was 22.2%. Metabolic syndrome, hyperglycemia, and dyslipidemia were presents among 23.1%, 32.4%, and 48.1%, respectively. BMI (between 25.8Kg/m2 and 28.0 Kg/m2), strongly predicted hyperglycemia, MetS, and dyslipidemia. Additionally, the range of optimal cut-off values of central obesity indices including WC (84.0cm to 90.0 cm), WHR (0.85-0.89 cm/cm), WHtR (0.52-0.61 cm/cm) and AVI (14.3 to 16.5) better predicted hyperglycaemia, MetS and dyslipidaemia. Only BMI and BAI were sign can't predictors of hypertension.*

Conclusion: *Cardiometabolic risk factors including hypertension, hyperglycemia, dyslipidemia and MetS are high among women with primary infertility. BMI proved superior in predicting cardiometabolic risk factors among primary infertile women.*

Introduction

Infertility is a recognized global problem, affecting on average 8% to 12% of couples worldwide [1]. According to studies within the African continent, as high as 30.0% prevalence of infertility among couples has been reported [2-4]. In Ghana, the prevalence rate of infertility is 11.8% among women and 15.8% among men [5]. According to the reports of Tabong and Adongo, infertility affects the challenge of social stigmatization denied membership in the ancestral world and family stress [6]. Thus, women with subfertility may suffer from stress, depression, and anxiety, which has a contributing role in cardiovascular disease (CVD) [7]. Apart from the social effects of infertility, it has been associated with disturbances in glucose and lipid metabolism. A study by Verit et al., showed that women with unexplained infertility have an atherogenic lipid pro le and elevated high-sensitivity C-reactive protein levels. Infertility may share some common pathways with CVD according to a report by Parikh et al., [8, 9]. Oxidative stress is common in infertile patients with conditions such as endometriosis, polycystic ovarian syndrome (PCOS), obesity, and unexplained infertility, which exaggerate the risk of cardio-metabolic abnormalities [10].

The relationship between obesity and reproductive functions has been known for many years [11, 12]. Obesity in recent years has been reportedly high among women with fertility issues [13]. Obesity complicates the treatment of anovulatory infertility and require a higher dosage of gonadotropin, respond poorly to ovarian stimulation, and have a higher risk of miscarriage [14, 15]. The obese women with infertility also have an exaggerated risk of developing worst cardiovascular outcomes due to interrelated mechanisms of androgen effect and long-term management [8, 16]. Infertile patients with BMI >24kg/m^2 have been shown to have higher systolic pressure and post-insulinemia levels in comparison with patients with normal BMI [17].

Several studies have evaluated the link between adiposity indices and cardiometabolic risk, but the criterion of these indices for identifying cardiometabolic risk factors among infertile women is less explored. Also, sensitive and specific techniques including dual-energy X-ray absorptiometry (DXA), computed tomography (CT) and magnetic resonance imaging (MRI), for sassing body compositions is less accessible and expensive [18-21]. Thus, inexpensive measurements of adiposity with equivalent sensitivity for predicting MetS and its components merit attention and would provide important practical applications among infertile women. This study, therefore, evaluated the use of simple anthropometric indices, which has been validated in literature as an index of adiposity for predicting cardiometabolic risk factors among infertile women in a Ghanaian population [22, 23].

Methods

Study Design/setting

A cross-sectional study was carried out at the Manhyia Government Hospital from September 2018 to March 2019. Target Population. All patients visiting the hospital for infertility issues were included as a sample. Sub-fertile or infertile women above 18 years who were proved psychologically, physically and socially t after an investigation by the gynaecologist were selected to partake in the study. Women presenting with infectious conditions such as human immunodeficiency virus (HIV), Hepatitis B and C, and tuberculosis were excluded from the study. Moreover, patients on any kind of hormone treatment or treatment with antihypertensive, antidiabetic and statins were excluded from the study. Primary infertility was de ned as couples that had never conceived despite exposure to the risk of pregnancy for 1 year.

Sample Size

Using a proportionate ratio of infertility among women in Ghana to be 11.8% [5], at a confidence interval of 95%, with 5% margin of error, the minimum required sample size for the study was 160 using the Cochrane formulae [24]. However, to adjust for a non-response rate of 25.0% and ensure high statistical power, a total of 216 samples were used.

Blood Pressure Measurement

Participants were asked to complete a self-administered questionnaire which asked about their age, and years of infertility. Aetiology of infertility was extracted from their folders. Measurements of blood pressure were measured with the subject being in the seated position using an automated BP monitor (Omron HEM-5001, Kyoto, Japan) from the subject's right arm. Three readings were recorded 3 to 5 minutes apart and the average of two closest systolic blood pressure (SBP) and diastolic blood pressure (DBP) readings were taken as the final reading.

Anthropometric measurements

Weight of each participant was measured using a platform electronic scale to the nearest 0.1kg. Waist circumference (WC) and hip circumference (HP) were measured using a non-extensible but exible tape measure at the point of the umbilicus and the maximal gluteal position, respectively. Portable height-rod stadiometer was used for body height; the subject stood straight, with feet placed together and at on the ground.

Derived Anthropometric Indices

BMI was calculated as body weight in kilograms divided by height in meters squared (kg/m2). Waist-to-hip ratio and waist-to-height ratio were estimated from the ratio of the waist (cm) to hip (cm) and waist (cm) to height (cm), respectively. Other indices like abdominal volume index (AVI) and body adiposity index (BAI) were calculated using the formulae below:

$$AVI = \frac{2cm \times (waist)^2 + 0.7cm \times (waist\text{-}hip)^2}{1000}$$

$$BAI = \frac{hip\ circumference\ (cm)}{height^{1.5}} - 18$$

Sample Collection and Analysis

Five millilitres (ml) of fasting venous blood sample was drawn from the subject using standard venepuncture techniques. Two ml blood was dispensed into vacutainers containing sodium fluoride for estimation of plasma glucose (FBS). The remaining three ml was collected into serum separator tubes. Serum separated after clotting was used for routine biochemical analysis of triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C). All biochemical analysis was done using BT® 3000 Random Access Chemistry System (Elan Diagnostic Systems, USA).

Definition of clinical characteristics

Mets were de ned according to the National Cholesterol Education Program Adult Treatment Panel III recommendation [27]. This criterion is based on the presence of at least three of the following five risk factors: (1) WC ≥ 88 cm; (2) serum TG ≥ 1.7 mmol/L; (3) HDL-C <1.30 mmol/L; (4) systolic and/or diastolic blood pressure ≥ 130- or 85-mm Hg, respectively; and (5) fasting plasma glucose (FBS) > 6.1 mmol/L. Since WC was used in the evaluation of MetS and cardiovascular risk a de nation excluding WC criteria was used. Hence, MetS-adjusted criteria were determined as at least three of the four instead of five risk factors [28]. Subjects with one or more of the following results were considered to be dyslipidemia: TC ≥6•22 mmol/L, TG ≥2•26 mmol/L, LDL-C ≥4•14 mmol/L or HDL-C <1•03 mmol/L [27]. Hypertension was de ned as either a systolic blood pressure of ≥140 mmHg and/or diastolic blood pressure of ≥90 mm Hg.

Statistical analysis

Normal distribution of data was examined using the Kolmogorov–Smirnov test. Categorical data were expressed as frequencies and chi-square analyses were performed for comparing categorical variables. Pearson correlation analysis was performed to examine the relationship between anthropometric variables and cardiometabolic risk factors. The predictive ability of adiposity indices for cardiometabolic risk factors was assessed using the highest combination of sensitivity and speci city from Receiver operative characteristics (ROC) curve analysis, Cohen's kappa analysis and logistic regression analysis. Covariates used in the

multivariate regression analysis are shown in Supplementary Table 3. The analysis was conducted using the Statistical Package for Social Sciences (SPSS 25.0) and p-value <0.05 was considered statistically significant.

Results

The mean age of the study subjects was 30.3 (±5.7 SD) and the median duration of infertility was 3.0 (2.0 to 4.0 interquartile range). Respondents with tubal factors as the cause of infertility were most 48 (22.2%), followed by malefactors 36 (16.7%), other causes 34 (15.7%), hyperprolactinemia 30 (13.9%), unexplained causes 28 (13.0%) and polycystic ovarian syndrome 24 (11.1%). The mean BMI was 28.6 Kg/m2. The means of central obesity measures were respectively, 88.6 cm, 0.87 and 0.56 for WC, WHR, and WHtR [Supplementary Table 1].

Average BMI was significantly higher among with PCOS, Male factor and other causes of infertility compared women with unexplained causes of infertility (p-value =0.041). Also, mean BAI was significantly lower among women with PCOS associated infertility compared with others with other causes (p-value =0.007). Although not statistically significant (p-value =0.070), the mean fasting blood glucose level was high for women with Male factor (6.4 mmol/L) and PCOS (6.5 mmol/L) associated infertility. Total cholesterol levels were significantly higher for Male factor (6.9 mmol/L) and PCOS (6.7 mmol/L) associated infertility, compared with others (p-value <0.0001). Compared with Male factor and PCOS associated infertility (p-value <0.05), the levels of Triglycerides and LDL-C was lower for women with uterine and unexplained causes of infertility. Systolic blood pressure was significantly higher among women with male factor (131.8 mmHg), unexplained (131.5 mmHg) and other (132.6 mmHg) cause of infertility. The prevalence of hypertension was higher among women with other causes of infertility 14/34 (41.2%) and male factor 14/36 (38.9%). Also, hyperglycemia was high among male factor 18/36 (50.0%), PCOS 10/24 (41.7%), other cause 14/34 (41.2%) and tubal factor 16/48 (33.3%) associated infertile women. The highest prevalence of dyslipidemia was observed among women with Male factor associated infertile women 26/36 (72.2%), followed by PCOS 16/24 (66.7%) and tubal factor 22/48 (45.8%). No prevalence of MetS was observed among women with unexplained causes of infertility [Table 1].

Table 1: Characteristics of the study participants strati ed by causes of infertility

Variables	Hyper-prolactinemia	Tubal factor (N=48)	Male factor (N=36)	PCOS (N=24)	Uterine causes (N=16)	Unexplained Causes (N=28)	Other causes (N=34)	P-value
Anthropometric indices								
Body mass index (Kg/m^2)	28.8 (0.80)	28.5 (0.91)	29.7 (0.91)	29.8 (1.12)	27.5 (1.13)	25.9 (0.77)	29.6 (0.65)	0.041
Waist Circumference (cm)	84.9 (1.45)	90.5 (2.14)	88.1 (1.36)	88.6 (2.1)	86.4 (2.48)	88.1 (2.44)	90.8 (1.57)	0.342
Waist-to-hip ratio	0.85 (0.007)	0.88 (0.016)	0.87 (0.073)	0.89 (0.010)	0.88 (0.023)	0.86 (0.014)	0.87 (0.007)	0.422
Waist-to-height ratio	0.54 (0.009)	0.56 (0.014)	0.56 (0.007)	0.54 (0.013)	0.54 (0.013)	0.55 (0.014)	0.57 (0.009)	0.372
Body adiposity index	31.8 (0.97)	32.1 (0.87)	33.5 (0.79)	29.2 (0.80)	31.0 (0.92)	32.8 (0.96)	34.3 (0.78)	0.007
Abdominal volume index	14.7 (0.51)	17.0 (0.79)	15.8 (0.47)	16.0 (0.72)	15.3 (0.90)	16.0 (0.91)	16.8 (0.58)	0.243
Biochemical parameters								
Fasting plasma sugar	5.3 (0.38)	5.7 (0.37)	6.4 (0.42)	6.5 (0.63)	5.0 (0.25)	5.1 (0.22)	5.8 (0.33)	0.070
Total Cholesterol	5.3 (0.27)	5.8 (0.23)	6.9 (0.51)	6.7 (0.58)	4.7 (0.17)	4.7 (0.24)	5.3 (0.22)	<0.0001
Triglyceride	1.6 (0.19)	1.3 (0.08)	1.6 (0.21)	1.7 (0.18)	1.2 (0.13)	1.0 (0.06)	1.5 (0.10)	0.028
HDL-C	1.48 (0.10)	1.59 (0.08)	1.57 (0.07)	1.85 (0.17)	1.58 (0.15)	1.58 (0.11)	1.60 (0.14)	0.556
LDL-C	3.45 (0.27)	3.91 (0.24)	5.04 (0.48)	4.46 (0.44)	2.85 (0.18)	2.88 (0.23)	3.38 (0.17)	<0.0001

Blood pressure indices								
SBP (mmHg)	129.0 (2.80)	126.7	131.8	122.6	126.0	131.5 (1.68)	132.6	0.040
		(1.52)	(2.52)	(2.22)	(3.64)		(2.57)	
DBP (mmHg)	77.7 (1.60)	79.0	81.1	72.3	78.8	77.6 (1.27)	82.2	<0.0001
		(1.13)	(1.24)	(2.00)	(1.26)		(0.67)	
Cardiometabolic factors[A]								
Hypertension	6	8	14	0	2	4 (14.3)	14	0.001
	(20.0)	(16.7)	(38.9)		(12.5)		(41.2)	
Hyperglycaemia	4 (13.3)	16	18	10	2	6 (21.4)	14	0.011
		(33.3)	(50.0)	(41.7)	(12.5)		(41.2)	
Dyslipidaemia	12 (40.0)	22	26	16	6	8 (28.6)	14	0.006
Metabolic	4	14	10	6	4	0	12	
	(13.3)	(45.8)	(72.2)	(66.7)	(37.5)		(41.2)	
syndrome	(29.2)	(27.8)	(25.0)	(25.0)		(25.0)		

The prevalence of hypertension among the study participants was 22.2%. Metabolic syndrome, hyperglycemia and dyslipidemia were presents among 23.1%, 32.4% and 48.1%, respectively [Figure 1].

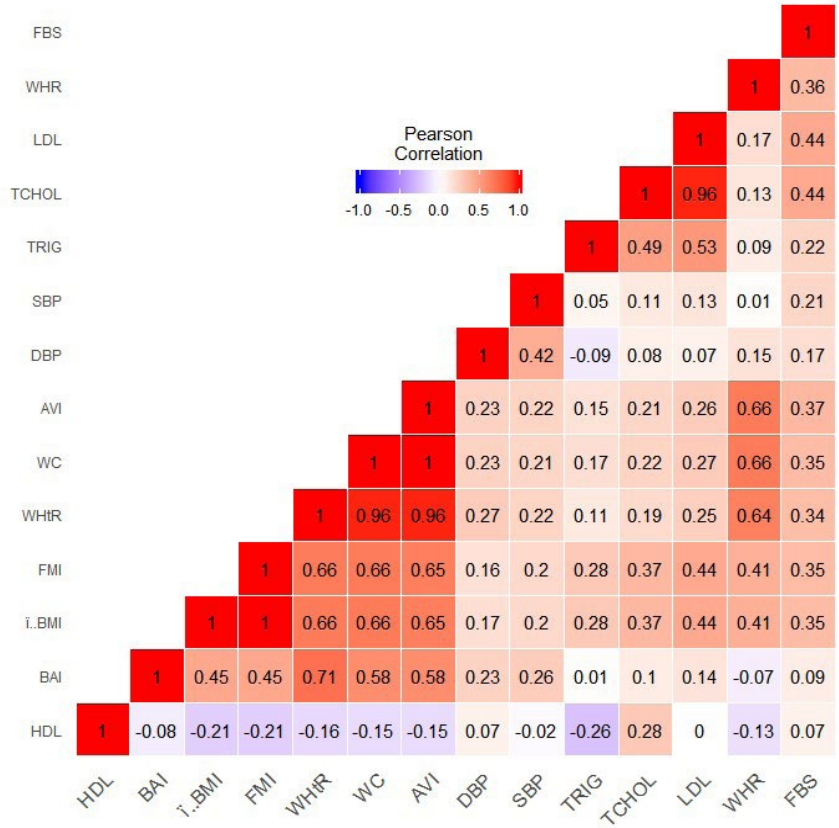

Figure 1: Prevalence of cardiometabolic factors among women with primary infertility

Figure 2 shows the correlation of anthropometric indices with cardiometabolic risk factors. A significant positive correlation was observed between adiposity indices and fasting plasma glucose except for BAI, which showed no significant correlation (p-value =0.337). A significant positive correlation was observed between TC and BMI (R=0.37, p-value <0.0001), WC (R=0.22, p-value =0.024), WHtR (R=0.19, p-value =0.044) and AVI (R=0.21, p-value =0.030). BMI showed a significant positive correlation with TG and LDL, but negative correlation with HDL-C. WC, WHtR and AVI showed a significant positive correlation with LDL-C. Also, all adiposity indices other than WHR showed a significant positive correlation with systolic blood pressure measurements.

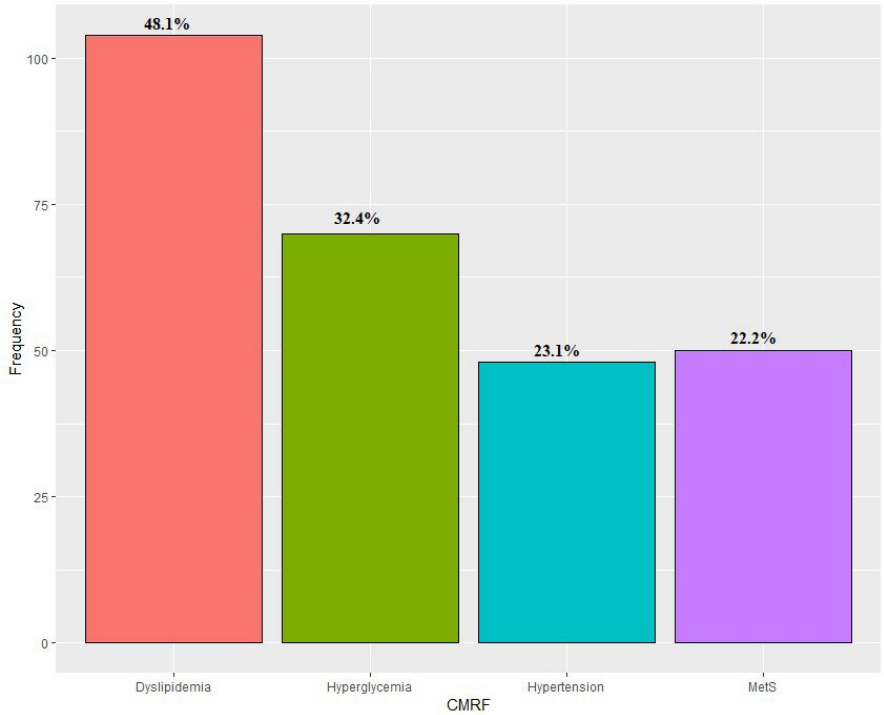

Figure 1: Correlation between anthropometric indices and cardiometabolic risk factors

Table 3 shows the criterion of anthropometric measurement for predicting hypertension. Among the indices considered, BMI, WC, WHR, WHtR, and AVI showed significant AUCs indicating their better suitability for predicting MetS, dyslipidemia and hyperglycemia. Also, BAI (AUC=0.721) and BMI (AUC= 0.641) better predict hypertension compared to other adiposity indices. BMI predictive cut-off values among women presenting with primary infertility proved to be the best anthropometric index, as it showed the largest AUC values for MetS (0.731), dyslipidemia (0.707) and hyperglycemia (0.759). Alternative measurements like AVI (AUC=0.749), WC (AUC=0.747) and WHtR (AUC=0.742) also proved to be better indices for predicting hyperglycemia. Moreover, central obesity indices (WC, WHR, and WHtR) and AVI proved a better alternative index for predicting MetS and dyslipidemia. The cut-off values for predicting MetS were as follows: WC = 90 cm; WHtR = 0.61 cm/cm; BMI = 28.0 kg/m^2; WHR = 0.89 and AVI= 16.5 units.

Table 2: Criterion of anthropometric measurements for predicting cardiometabolic risk factors among primary infertility patients

Variable	BMI	WC	WHR	WHtR	BAJ	AVI
Mets						
AUC	0.731	0.690	0.653	0.669	0.595	0.688
Sensitivity	0.760	0.680	0.640	0.400	0.398	0.680
Specificity	0.614	0.675	0.687	0.928	0.840	0.675
Criterion	>28.0	>90.0	>0.89	>0.61	>29.9	>16.5
Dyslipidaemia						
AUC	0.707	0.627	0.650	0.614	0.541	0.622
Sensitivity	0.654	0.692	0.712	0.750	0.788	0.712
Specificity	0.714	0.517	0.589	0.446	0.375	0.500
Criterion	>28.0	>84.0	>0.85	>0.52	>29.4	>14.3
Hyperglycaemia						
AUC	0.759	0.747	0.675	0.742	0.666	0.749
Sensitivity	0.914	0.743	0.629	0.686	0.686	0.771
Specificity	0.534	0.671	0.726	0.726	0.630	0.671
Criterion	>25.8	>88.0	>0.89	>0.57	>32.1	>15.6

Hypertension						
AUC	0.641	0.565	0.437	0.592	0.721	0.570
Sensitivity	0.500	0.417	0.333	0.583	0.875	0.417
Specificity	0.810	0.738	0.604	0.595	0.548	0.750
Criterion	>33.2	>95.0	>0.90	>0.56	>31.3	>18.4

Table 4 shows the logistic regression analysis of various anthropometric cut-off values predictive of cardiometabolic factors. The odds ratios (95% confidence interval) for BMI, WC, WHR, WHtR and AVI were 4.96 (2.36-10.40), 4.56 (2.249.26), 5.35 (2.53-11.31), 7.45 (3.24-17.10) and 4.56 (2.24-9.26), respectively for predicting MetS. However, in the multivariate model, WC and AVI were no longer significant in predicting MetS. The odds ratios for predicting dyslipidemia was significant for BMI, WC, WHR, WHtR, and AVI in the univariate-adjusted model. However, in the multivariate model, only BMI and WHR were significant for predicting dyslipidemia. BMI (OR=7.52), WHR (OR=5.71) and BAI (OR=3.49) proved to be the most significant adiposity indices for predicting hyperglycemia.

Table 3: Logistic regression analysis of various anthropometric cut-off values predictive of cardiometabolic factors

Variable	Univariate-adjusted OR (95% CI)	P-value	Multivariate OR (95% CI)	P-value	Kappa
Mets					
BMI	4.96 (2.36-10.40)	<0.0001	3.35 (1.41-7.93)	0.006	0.263
WC	4.56 (2.24-9.26)	<0.0001	0.95 (0.36-2.48)	0.917	0.280
WHR	5.35 (2.53-11.31)	<0.0001	2.77 (1.29-5.93)	0.009	0.264
WHtR	7.45 (3.24-17.10)	<0.0001	4.88 (1.81-13.21)	0.002	0.375
AVI	4.56 (2.24-9.26)	<0.0001	-	-	0.280
Dyslipidaemia					
BMI	3.71 (2.00-6.86)	<0.0001	3.98 (2.03-7.79)	<0.0001	0.332
WC	2.66 (1.45-4.86)	0.002	0.23 (0.02-2.61)	0.237	0.209
WHR	2.77 (1.51-5.07)	0.001	3.47 (1.81-6.65)	<0.0001	0.299
WHtR	2.43 (1.30-4.52)	0.005	0.92 (0.26-3.29)	0.903	0.194
AVI	2.97 (1.61-5.47)	<0.0001	3.96 (0.51-30.75)	0.189	0.210
Hyperglycaemia					
BMI	13.43 (5.26-34.30)	<0.0001	7.52 (2.69-21.02)	<0.0001	0.365
WC	5.61 (2.87-10.94)	<0.0001	0.19 (0.02-1.63)	0.129	0.373
WHR	4.05 (2.13-7.71)	<0.0001	5.71 (2.33-14.00)	<0.001	0.337
WHtR	5.72 (2.93-11.16)	<0.0001	1.28 (0.45-3.66)	0.650	0.386
BAI	4.32 (2.20-8.49)	<0.0001	3.49 (1.42-8.56)	0.006	0.258
AVI	5.67 (2.86-11.22)	<0.0001	4.34 (0.60-31.64)	0.147	0.366
Hypertension					
BMI	4.15 (2.07-8.33)	<0.0001	2.47 (1.19-5.13)	0.016	0.292
BAI	8.52 (3.40-21.34)	<0.0001	6.35 (2.48-16.28)	<0.0001	0.278

Univariate-adjusted (adjusted for age, duration of infertility, causes of infertility). OR-odds ratios; CI-condense interval. Values highlighted in back denotes statistically significant variables.

Discussion

Cardiovascular risk factors are common symptoms associated with women with infertility [29]. We observed the prevalence of hypertension, hyperglycemia, dyslipidemia and MetS of 22.2%, 23.1%, 32.4%, and 48.1%, respectively among women with primary infertility. The common cardiovascular risk symptoms including dyslipidemia, hyperglycemia, hypertension and metabolic syndrome among infertile women have been thought to be mediated by pathways based on the aetiology of infertility [28]. Previous studies by Valkenburg et al., and Zhang et al., has reported a high prevalence of dyslipidemia among infertile women with the polycystic ovarian syndrome as the underlying cause. Also, worse cardiometabolic risk pro le among infertile women with hyperandrogenic phenotypes have been documented [30-32]. Our finding showed that women with hyperprolactinemia, uterine and unexplained cause of infertility were less likely to present with hypertension, hyperglycaemia and dyslipidemia [Supplementary Table 2]. However, a malefactor associated infertility; infertile women with at least two of the following, ovulatory problems, endometriosis, hyperprolactinemia, tubal factors as well as infertile women with PCOS as the underlying cause was associated with increased likelihood cardiometabolic risk factors. Thus, our

endings in line with previous endings, present a picture of a high prevalence of cardiometabolic risk factors among women with infertility which is largely dependent on the aetiology of infertility, and factors including hyperandrogenism and obesity-associated as predisposing factors [33]. Pasquali in a study reported that hormonal alterations among infertile women may play an important role in the pathophysiology of obesity and its associated metabolic and cardiovascular comorbidities [34].

Consistent with literature, our study demonstrated that adiposity indices are associated with cardiometabolic risk factors with stronger associations observed for the index that reflects general adiposity (i.e., BMI). Additionally, central adiposity indices (WC, WHR, and WHtR) proved stronger in predicting MetS, dyslipidemia and hyperglycemia. Consistent with our findings, studies evaluating cardiovascular risk factors among infertile women have consistently reported BMI and WC as the strongest predictor [29, 33]. In a study by Gadelha et al., comparing adiposity indices for predicting MetS among postmenopausal women reported that central adiposity indices such as WC and WHtR strongly predict MetS, which is partly consistent with our present ending. In a study among women of different socioeconomic class, BMI was reported as the best indicator for predicting metabolic abnormalities [35, 36]. Gowda and Philip indicated that indices like AVI and WC could be used along with BMI in the prediction of multiple metabolic abnormalities, which is consistent with our endings. Although the observations of this study are partly comparable with previous reports, it is important to note that infertile women show characteristic differences in body composition and fat distribution patterns when compared with healthy, fertile, age-matched counterparts [37].

There is a paucity of cut-off values in the literature regarding the determination of cardiometabolic risk factors among women with primary infertility. Thus, our study was designed to better de ne cardiometabolic risk factors in a sample of women with primary infertility from Ghana. Although several studies have been conducted to evaluate optimal cut off values of adiposity indices for predicting cardiometabolic risk factors among women, results specifically for women presenting with primary infertility, whose body composition and fat distribution patterns differ when compared with healthy, fertile, age-matched counterparts remain to be de ned. The best predictive cut-off values for BMI (>25.8Kg/m2 and >28.0 Kg/m2), strongly predicted hyperglycemia, MetS, and dyslipidemia. Additionally, the range of optimal cut-off values of central obesity indices including WC (84.0cm -90.0 cm), WHR (0.85-0.89 cm/cm), WHtR (0.52-0.61 cm/cm) as well as AVI (14.3 to 16.5) which consider regional fat distribution and are better re sections of vascular anatomy and metabolic activity, better predicted MetS, dyslipidaemia and hyperglycaemia. The criterion for WHtR (>0.61) was associated with the highest odds and better agreement for predicting MetS, possibly because it re acts the ratio between WC and height. Thus reducing the chances of overestimating or underestimating central obesity, similar to endings by Gadelha et al., among postmenopausal women [38].

The limitation of the study is its cross-sectional design which precludes cause-effect inferences. Furthermore, the number of volunteers participating in the study and the sample frame was relatively small; even though the sample size calculation was designed to represent infertile women in Ghana. Thus, it may not be representative of the whole country of Ghana since the study was localized at the Komfo Anokye Teaching Hospital. Also, there was a lack of national cut-off data on adiposity indices currently used in Ghana for women other than the one established by the World Health Organization [39]. However, our endings suggest that to predict and de ne intervention strategies for cardiometabolic risk among women with primary infertility, the criterion for de ning overweight/obesity in this study could be useful for weight-control programs.

Conclusion

Consistent with the literature, cardiometabolic risk factors including hypertension, hyperglycemia, dyslipidemia and MetS is high among women with primary infertility. Various adiposity indices are associated with cardiometabolic risk factors in primary infertile women.

Declarations

Funding

No funding was obtained for the study

Competing Interests

The authors declare that they have no competing interests

Ethical Statement

This study was approved by the Manhyia Government Hospital Kumasi. All patients enrolling in the study completed a written informed consent form following the Helsinki Declaration.

Consent for Publication

Not applicable

Acknowledgements

The Authors acknowledge the hard work of the Staff of Manhyia Government Hospital, in their effortless contribution to the success of this study.

Availability of Data

The datasets used and analysed during the study are available from the corresponding author on reasonable request.

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Supplementary material

Supplementary Table 1: Basic characteristics of the study participants

Variable	Response (n=216)
Duration of infertility^	3.0 (2.0-4.0)
Age (years)*	30.3±5.7
Aetiology of infertility+	
Hyperprolactinemia	30 (13.9)
Tubal factors	48 (22.2)
Male factors	36 (16.7)
PCOS	24 (14.8)
Uterine causes	16 (7.4)
Unexplained causes	28 (13.0)
Other	34 (15.7)
Body mass index (Kg/m^2)*	28.6±5.2
Waist Circumference (cm)*	88.6±11.1
Waist-to-hip ratio*	0.87±0.07
Waist-to-height ratio)	0.56±0.07
Body adiposity index*	32.3±5.2
Abdominal volume index*	16.1±4.1
Fasting plasma sugar (mmol/L)*	5.7±2.3
Total Cholesterol (mmol/L)*	5.7±2.1
Triglyceride (mmol/L)*	1.4±0.8
HDL-C (mmol/L)*	1.60±0.62
LDL-C (mmol/L)*	3.8±1.9
SBP (mmHg)*	128.9±13.3
DBP (mmHg)*	78.7±7.8

PCOS-polycystic ovarian syndrome; SBP-systolic blood pressure; DBP- diastolic blood pressure; ^ values are presented as median (interquartile range); * values are presented as mean ± SD, + values are presented as frequency (percentage). ***Other causes (at least two of ovulatory problems, endometriosis, hyperprolactinemia, tubal factors).***

Supplementary Table 2: Univariate analysis of patients' dynamics and cardiometabolic risk factors prevalence

Variables	Hypertension	Hyperglycaemia	Dyslipidaemia	MetS
Age (years)	1.06 (1.0-1.11)	1.0 (0.95-1.05)	1.0 (0.96-1.05)	0.97 (0.91-1.03)
Duration of infertility	1.0 (0.93-1.08)	0.98 (0.91-1.05)	0.91 (0.85-0.99)*	0.91 (0.81-1.02)
Hyperprolactinemia	0.86 (0.33-2.23)	0.28 (0.09-0.84)*	0.68 (0.31-1.49)	0.47 (0.16-1.41)
Tubal factor	0.64 (0.28-1.48)	1.07 (0.53-2.09)	0.89 (0.47-1.69)	1.51 (0.73-3.11)
Male factor	2.73 (1.27-5.88)*	2.46 (1.19-5.10)*	3.40 (1.55-7.47)**	1.35 (0.60-3.03)
PCOS	N/A	1.57 (0.66-3.74)	2.36 (0.96-5.78)	1.12 (0.42-3.0)
Uterine causes	0.48 (0.11-2.18)	0.28 (0.06-1.26)	0.62 (0.22-1.78)	1.12 (0.34-3.63)
Unexplained cause	0.55 (0.18-1.66)	0.53 (0.20-1.37)	0.38 (0.16-0.91)*	N/A
Others	3.05 (1.40-6.63)**	1.58 (0.74-3.34)	0.72 (0.34-1.50)	2.07 (0.94-4.56)

Other causes (at least two of ovulatory problems, endometriosis, hyperprolactinemia, tubal factors).
* Significant at 0.05 α-level; ** significant at 0.01 α-level.

Supplementary Table 3: Stepwise regression analysis regression analysis for the selection of covariates

Variables	Hypertension	Hyperglycaemia	Dyslipidaemia	MetS
Hyperprolactinemia	N/A	N/A	N/A	N/A
Tubal factor	N/A	2.58 (1.09-6.11)*	N/A	N/A
Male factor	3.25 (1.42-7.40)**	5.17 (2.10-12.70)**	3.94 (1.78-8.74)**	N/A
PCOS	0.0	3.69 (1.33-10.24)*	3.03 (1.22-7.51)*	N/A
Uterine causes	N/A	N/A	N/A	N/A
Unexplained cause	N/A	N/A	N/A	N/A
Others	3.57 (1.55-8.22)*	3.62 (1.44-9.09)**	N/A	N/A
Unexplained cause	0.55 (0.18-1.66)	0.53 (0.20-1.37)	0.38 (0.16-0.91)*	N/A
Others	3.05 (1.40-6.63)**	1.58 (0.74-3.34)	0.72 (0.34-1.50)	2.07 (0.94-4.56)

Other causes (at least two of ovulatory problems, endometriosis, hyperprolactinemia, tubal factors). N C-not computed. * Significant at 0.05 α-level; ** significant at 0.01 α-level.