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The discriminatory capability of anthropometric measures in predicting reproductive outcomes in Chinese women with PCOS

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Abstract

Objective Obesity is a common feature in women with polycystic ovary syndrome (PCOS) and potentially significantly influences reproductive function. However, opinions are divided as to which factor is a more appropriate obesity predictor of reproductive outcomes. The aim of this study was to investigate the discriminatory capability of anthropometric measures in predicting reproductive outcomes in Chinese women with PCOS.

Methods A total of 998 women with PCOS from PCOSAct were included. Logistic regression models were used to compute the odds ratios (ORs) and 95% confidence interval (95% CIs) to assess the effect of anthropometric measures, including body mass index (BMI), waist circumference (WC), hip circumference (HC), the waist–hip ratio (WHR) and the waist–height ratio (WHtR), on reproductive outcomes. The discrimination abilities of the models were assessed and compared based on the area under the receiver operating characteristic curve (AUC), Akaike's information criterion (AIC) and integrated discrimination improvement (IDI).

Results Among PCOS women, there was a graded association between anthropometric measures and predicted reproductive outcomes across quintiles of anthropometric measures, including a linear association among WHR, BMI and reproductive outcomes and among waist circumference, WHtR and live birth, pregnancy, and ovulation. However, only a linear association was noted between the hip and ovulation. C-statistic comparisons and IDI analyses revealed a trend towards a significant superiority of BMI for ovulation and WHR for live birth, pregnancy and conception in the models. Combining obesity variables improved discrimination in the multivariable models for reproductive outcomes.

Conclusions Our findings support that BMI is a better predictor of ovulation and that the WHR is a better predictor of live birth, pregnancy and conception, whereas the combination of obesity variables contributes to the discrimination of reproduction.

Keywords Obesity, Polycystic ovary syndrome, Reproductive outcomes, Waist–hip ratio, Body mass index

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Introduction

Obesity is responsible for an increased risk of subfecundity and infertility, which are related mainly to impairments in the hypothalamic–pituitary–ovarian axis, poor oocyte quality and altered endometrial receptivity [1, 2]. Obese women have poorer reproductive outcomes regardless of the mode of conception [3]. Polycystic ovary syndrome (PCOS) is one of the leading causes of infertility and is the most common endocrine disorder in women of reproductive age. The diagnostic criteria include hyperandrogenism, oligoanovulation, and polycystic ovary morphology [4], but many women with PCOS are overweight [5]. Obesity has a strong influence on distinct PCOS phenotypes and affects the management of symptoms and fertility outcomes [6]. Leptin released from adipose tissue disrupts steroidogenesis, folliculogenesis, and oocyte maturation in granulosa and follicle cells via leptin receptors present in the ovary [7]. Increases in leptin accompany adipose tissue growth and lead to dysregulation of glucose and fatty acid metabolism, which further affects the reproductive axis [8]. Obesity and hormone levels interact and thereby influence reproduction. Compared with age- and weight-matched women with more peripheral obesity, women with a central body fat distribution present lower sex hormone-binding globulin (SHBG) concentrations. Central obesity in women leads to elevated serum insulin levels, which subsequently contributes to the reduced synthesis of SHBG [7]. This insulin resistance and hyperinsulinaemia ultimately affect downstream targets such as the ovaries [9].

Body mass index (BMI) has been routinely used in clinical and public health practices for decades to identify individuals and populations at risk of future obesity-related conditions, such as cardiovascular disease and diabetes mellitus [10]. Other common surrogates of obesity include waist circumference (WC) and the waist–hip ratio (WHR). Waist circumference and the WHR are the most common proxy measures of visceral adipose tissue (VAT), as they are strongly correlated with increased risks of numerous health outcomes as well as mortality in the majority of populations [11]. Accumulating evidence consistently shows that both a larger waist and a narrow hip increase the risk of cardiovascular disease (CVD), coronary heart disease, diabetes and premature death [12, 13]. The relationships between BMI and other indices of obesity and the risk of developing reproductive abnormalities in individuals with PCOS have been well established [14]. However, opinions are divided as to which is a more appropriate predictor of obesity, and several studies have recommended the use of anthropometric measures that capture abdominal obesity [WC, WHR, or waist–height ratio (WHtR)] as alternatives to and in addition to BMI in assessing the prediction of diseases in clinical practice and public health in general [14–16]. Data regarding racial/ethnic and regional differences in the obesity phenotype among women with PCOS are inconsistent. Accordingly, the present study aimed to assess and compare the strength and discriminatory power of BMI and other anthropometric measures, such as WC, HC, WHR and WHtR, in predicting screen-detected reproductive outcomes in a Chinese population with PCOS.

Methods

Study design

This study is a post hoc analysis of obesity and reproductive outcome data from PCOSAct (NCT01573858), which is a multicentre, two-by-two factorial randomized controlled clinical trial conducted from 2012 to 2015 in mainland China [17].

Participants

All 998 women aged between 20 and 40 years were diagnosed with PCOS according to the modified Rotterdam criteria and were randomized to one of four treatments: (A) active acupuncture plus clomiphene; (B) control acupuncture plus clomiphene; (C) active acupuncture plus clomiphene placebo; and (D) control acupuncture plus clomiphene placebo for four menstrual cycles. The inclusion criteria included oligomenorrhea (defined as an intermenstrual interval > 35 days and < 8 menstrual bleeds in the past year) or amenorrhea (defined as an intermenstrual interval > 90 days), together with biochemical/clinical hyperandrogenism (hirsutism determined by modified Ferriman-Gallwey score ≥ 5) and/or polycystic ovaries (≥ 12 antral follicles 2–9 mm or ovarian volume ≥ 10 cm^3). The following exclusion criteria were employed: (A) exclusion of other endocrine disorders resembling PCOS, including hyperprolactinemia, uncorrected thyroid disease, type I or type II diabetes, and Cushing's syndrome; (B) use of hormonal or other medications, including Chinese herbal prescriptions, in the past 3 months; (C) pregnancy within the past 6 weeks; (D) within 6 weeks postabortion or postpartum; (E) breastfeeding within the last 6 months; or (F) not willing to give written consent to the study. All the women signed informed consent before joining the study. This study is registered at ClinicalTrials.gov with the identifier NCT01573858.

Data collection and measurement

Baseline information on demographic characteristics and reproductive outcomes was collected using a structured questionnaire. Body weight, standing height, and waist and hip circumferences were measured by study personnel according to the standard protocol. Maternal BMI was calculated according to the following formula:

BMI=weight in kilograms divided by height in metres squared.

Reproductive outcomes

Live birth was defined as the delivery of a live-born infant (≥20 weeks gestation). Conception was defined as any positive serum level of human chorionic gonadotropin. Pregnancy was defined as an intrauterine pregnancy with foetal heart motion, as determined using ultrasonography. Ovulation was defined as a serum progesterone level within the standards of the local site laboratory (minimum value of the luteal phase).

Statistical analyses

All the data were analysed via SAS/STAT v.9.4 for Windows (SAS Institute Inc., Cary, NC, USA). Categorical variables are presented as counts (percentages), and continuous variables are reported as the means and standard deviations (SDs) or medians and interquartile ranges, as appropriate. Analysis of variance, the Kruskal–Wallis test, the chi-square test and Fisher's exact test were used to determine differences among the three groups, and Student's t test or the chi-square test and Fisher's exact test were used for pairwise comparisons between the groups. Logistic regression models were used to assess the independent associations between each morphometric variable and each reproductive outcome. This approach allows for the computation of the confidence interval (CI) for the referent category and allows for mutual comparisons of nonreferent categories, which is not possible via conventional approaches. The log-linearity of the associations between each morphometric variable and each reproductive outcome was explored. All the models were adjusted for treatment. The ability of adipometric variables to discriminate between participants who did and did not have reproductive outcomes was assessed via the area under the receiver operating characteristic curve (AUC) and integrated discrimination improvement (IDI), which measures the percentage increase in discriminatory ability when an extra variable is added to a prediction model. AUC comparisons were performed with nonparametric methods. The AUC was used to determine which measure best predicted reproductive outcomes. Sensitivity and specificity were calculated to obtain operative cut-offs that can be used to identify reproductive outcomes. Youden's index was used to identify the best value of the index for selecting the optimum cut-off point. Bootstrap percentile techniques were used to derive the 95% CI for the IDI estimates. The likelihood ratio x2 statistics for each event category were calculated by comparing multivariate regression models with and without a single adipometric variable to assess improvement in model fit. We also calculate the Akaike information criterion (AIC), which is a measure of the trade-off between the goodness-of-fit of the regression model and the complexity of the model. Finally, we assessed the calibration of the regression models, for which we used the Hosmer and Lemeshow goodness-of-fit test, which assesses the agreement between the probability of prevalent diabetes estimated by the regression models and the observed prevalence of diabetes in the study population. Secondary analyses were conducted to test for the combination of anthropometric variables (BMI+WC or BMI+WHR), BMI, and WC in logistic regression models.

Results

Characteristics of the study participants

The characteristics of the 998 PCOS women from PCOSAct are summarized in Table 1. The study included 205 women with live births, 218 pregnant women, 320 women who conceived and 780 ovulating women. A lower weight, BMI, waist circumference, waist/hip ratio, and waist/height ratio were observed among women with live births compared with those without live births ($p<0.05$), among pregnant women compared with nonpregnant women ($p<0.05$), among women who conceived compared with those who did not conceive ($p<0.05$), and among ovulating women compared with nonovulating women ($p<0.05$). We compared the characteristics of the different reproductive outcomes in Table 1 and found that women with live births had higher SHBG, oestradiol and LH/FSH ratios but lower FAI, insulin, HOMA-IR, triglyceride, cholesterol and LDL-C values than women without live births did ($p<0.05$). Compared with nonpregnant women, pregnant women were more likely to have higher SHBG, oestradiol, and LH/FSH ratios and lower free testosterone, FAI, insulin, HOMA-IR, triglyceride, cholesterol, and LDL-C levels ($p<0.05$). Compared with women who did not conceive, women who conceived had higher SHBG, oestradiol, and LH/FSH ratios and lower free testosterone, FAI, and triglyceride levels ($p<0.05$). In addition, we also observed that ovulating women tended to have higher levels of SHBG and oestradiol and lower levels of total testosterone, free testosterone, FAI, LH, and LDL-C and LH/FSH ratios than nonovulating women ($p<0.05$).

Association of measures of obesity with predicted reproductive outcomes

Further correlation analysis (Fig. 1) revealed that 5 adipometric variables were significantly related to each other with the exception of a few combinations (WHR with hip circumference and BMI). A graded association was also noted between the adipometric variables and the predicted reproductive outcomes across quintiles of the adipometric variables (Table 2). This association was linear across WHR, BMI and reproductive outcomes (all

Table 1 Baseline characteristics of the study subjects by live birth, pregnancy, conception and ovulation in PCOSAct Trial

		Live birth			Pregnancy			Conception			Ovulation		
	Total	No live birth	Live birth	*P* value	No pregnancy	Pregnancy	*P* value	No conception	Conception	*P* value	No ovulation	Ovulation	*P* value
Age	27.9 ± 3.3 (998)	28.0 ± 3.4 (793)	27.5 ± 3.2 (205)	0.06	28.0 ± 3.3 (780)	27.6 ± 3.3 (218)	0.15	28.0 ± 3.4 (678)	27.7 ± 3.2 (320)	0.11	27.4 ± 3.4 (218)	28.1 ± 3.3 (780)	0.013
Height	161.2 ± 5.1 (998)	161.3 ± 5.0 (793)	161.1 ± 5.3 (205)	0.71	161.3 ± 5.1 (780)	161.1 ± 5.2 (218)	0.56	161.4 ± 5.0 (678)	160.9 ± 5.2 (320)	0.23	161.0 ± 5.2 (218)	161.3 ± 5.1 (780)	0.48
Weight	63.2 ± 12.4 (998)	63.7 ± 12.6 (793)	61.0 ± 11.6 (205)	0.006	63.7 ± 12.5 (780)	61.2 ± 11.8 (218)	0.007	64.0 ± 12.7 (678)	61.3 ± 11.6 (320)	0.001	66.7 ± 13.8 (218)	62.2 ± 11.8 (780)	< 0.001
BMI	24.2 ± 4.3 (997)	24.4 ± 4.3 (793)	23.5 ± 4.1 (204)	0.004	24.4 ± 4.3 (780)	23.5 ± 4.2 (217)	0.007	24.5 ± 4.3 (678)	23.6 ± 4.1 (319)	0.002	25.6 ± 4.7 (218)	23.8 ± 4.1 (779)	< 0.001
Waist	85.4 ± 11.5 (998)	86.0 ± 11.4 (793)	83.3 ± 11.6 (205)	0.002	86.0 ± 11.4 (780)	83.5 ± 11.7 (218)	0.006	86.0 ± 11.5 (678)	84.1 ± 11.4 (320)	0.013	88.2 ± 12.3 (218)	84.6 ± 11.1 (780)	< 0.001
Hip	98.5 ± 8.6 (998)	98.6 ± 8.6 (793)	97.7 ± 8.9 (205)	0.17	98.6 ± 8.6 (780)	97.9 ± 8.9 (218)	0.28	98.7 ± 8.6 (678)	97.9 ± 8.8 (320)	0.17	100.5 ± 9.1 (218)	97.9 ± 8.4 (780)	< 0.001
Waist/hip ratio	0.9 ± 0.1 (998)	0.9 ± 0.1 (793)	0.9 ± 0.1 (205)	< 0.001	0.9 ± 0.1 (780)	0.9 ± 0.1 (218)	< 0.001	0.9 ± 0.1 (678)	0.9 ± 0.1 (320)	0.011	0.9 ± 0.1 (218)	0.9 ± 0.1 (780)	0.035
Waist/height	0.5 ± 0.1 (998)	0.5 ± 0.1 (793)	0.5 ± 0.1 (205)	0.003	0.5 ± 0.1 (780)	0.5 ± 0.1 (218)	0.009	0.5 ± 0.1 (678)	0.5 ± 0.1 (320)	0.028	0.5 ± 0.1 (218)	0.5 ± 0.1 (780)	< 0.001
Ferriman-Gallwey score	3.0 ± 2.8 (998)	3.1 ± 2.8 (793)	2.9 ± 2.8 (205)	0.37	3.1 ± 2.8 (780)	2.9 ± 2.8 (218)	0.47	3.1 ± 2.9 (678)	2.9 ± 2.7 (320)	0.22	3.1 ± 3.1 (218)	3.0 ± 2.7 (780)	0.86
Acne	675/998 (67.6)	534/793 (67.3)	141/205 (68.8)	0.69	526/780 (67.4)	149/218 (68.3)	0.80	459/678 (67.7)	216/320 (67.5)	0.95	151/218 (69.3)	524/780 (67.2)	0.56
Acne score	439/998 (44.0)	351/793 (44.3)	88/205 (42.9)	0.97	346/780 (44.4)	93/218 (42.7)	0.96	292/678 (43.1)	147/320 (45.9)	0.22	89/218 (40.8)	350/780 (44.9)	0.36
Duration between menstruation periods, mean, days	69.5 ± 43.0 (998)	70.7 ± 45.0 (793)	65.0 ± 34.1 (205)	0.09	70.9 ± 45.3 (780)	64.5 ± 33.3 (218)	0.049	72.5 ± 46.1 (678)	63.2 ± 34.9 (320)	0.001	82.7 ± 52.9 (218)	65.9 ± 39.1 (780)	< 0.001
No.of menstrual cycles/per year, mean	6.2 ± 2.1 (998)	6.1 ± 2.1 (793)	6.4 ± 2.0 (205)	0.10	6.1 ± 2.1 (780)	6.4 ± 2.0 (218)	0.06	6.0 ± 2.2 (678)	6.5 ± 1.9 (320)	< 0.001	5.5 ± 2.3 (218)	6.4 ± 2.0 (780)	< 0.001
PCO morphology, any ovary -n. (%)	826/940 (87.9)	661/742 (89.1)	165/198 (83.3)	0.028	651/729 (89.3)	175/211 (82.9)	0.013	570/635 (89.8)	256/305 (83.9)	0.010	184/202 (91.1)	642/738 (87.0)	0.11
Ovary volume (any) = 10 -cm3 (%)	337/483 (69.8)	263/368 (71.5)	74/115 (64.3)	0.15	258/363 (71.1)	79/120 (65.8)	0.28	222/312 (71.2)	115/171 (67.3)	0.37	65/89 (73.0)	272/394 (69.0)	0.46
Polycystic ovaries -no. /total no. (%)	882/962 (91.7)	703/760 (92.5)	179/202 (88.6)	0.08	693/747 (92.8)	189/215 (87.9)	0.023	603/650 (92.8)	279/312 (89.4)	0.08	191/206 (92.7)	691/756 (91.4)	0.54
Total testosterone -ng/dL	48.0 ± 18.6 (959)	48.4 ± 18.4 (761)	46.4 ± 19.6 (198)	0.17	48.5 ± 18.4 (748)	46.3 ± 19.3 (211)	0.12	48.5 ± 18.6 (652)	46.9 ± 18.7 (307)	0.22	52.6 ± 19.1 (208)	46.8 ± 18.3(751)	< 0.001
Free testosterone -pg/ml	2.3 ± 0.8 (955)	2.3 ± 0.8 (758)	2.2 ± 0.9 (197)	0.06	2.3 ± 0.8 (746)	2.2 ± 0.9 (209)	0.035	2.3 ± 0.8 (648)	2.2 ± 0.8 (307)	0.016	2.5 ± 0.9 (205)	2.2 ± 0.8 (750)	< 0.001

Table 1 (continued)

		Live birth			Pregnancy			Conception			Ovulation		
	Total	**No live birth**	**Live birth**	***P* value**	**No pregnancy**	**Pregnancy**	***P* value**	**No conception**	**Conception**	***P* value**	**No ovulation**	**Ovulation**	***P* value**
Sex hormone-binding globulin -nmol/L	42.6 ± 30.4 (954)	41.2 ± 30.2 (755)	47.8 ± 30.7 (199)	0.007	41.1 ± 30.3 (742)	47.6 ± 30.6 (212)	0.006	40.7 ± 29.7 (645)	46.5 ± 31.6 (309)	0.005	34.3 ± 25.9 (204)	44.8 ± 31.2(750)	< 0.001
FAI	5.9 ± 4.4 (949)	6.2 ± 4.6 (752)	4.7 ± 3.3 (197)	< 0.001	6.2 ± 4.7 (739)	4.7 ± 3.3 (210)	< 0.001	6.2 ± 4.6 (643)	5.1 ± 3.9 (306)	< 0.001	7.7 ± 5.5 (204)	5.4 ± 4.0 (745)	< 0.001
Estradiol -pg/mL	73.4 ± 86.5 (958)	68.0 ± 61.0 (760)	94.3 ± 146.4 (198)	< 0.001	67.7 ± 61.1 (747)	93.6 ± 142.5 (211)	< 0.001	66.6 ± 58.3 (651)	88.0 ± 125.9 (307)	< 0.001	60.0 ± 26.6 (208)	77.2 ± 96.4 (750)	0.011
Progesterone -ng/ml	2.6 ± 5.1 (955)	2.5 ± 4.7 (758)	2.9 ± 6.4 (197)	0.28	2.5 ± 4.7 (745)	2.9 ± 6.2 (210)	0.32	2.4 ± 4.3 (650)	3.0 ± 6.5 (305)	0.10	2.9 ± 6.7 (207)	2.5 ± 4.5 (748)	0.29
Luteinizing hormone(LH) -mIU/mL	10.5 ± 5.9 (957)	10.3 ± 5.8 (760)	11.1 ± 6.2 (197)	0.11	10.4 ± 5.9 (747)	10.9 ± 6.2 (210)	0.28	10.4 ± 5.7 (651)	10.7 ± 6.4 (306)	0.43	11.5 ± 5.3 (207)	10.2 ± 6.1 (750)	0.006
Follicle stimulating hormone(FSH) -mIU/mL	6.1 ± 1.7 (957)	6.1 ± 1.6 (761)	6.2 ± 1.8 (196)	0.36	6.1 ± 1.6 (748)	6.2 ± 1.8 (209)	0.56	6.1 ± 1.6 (652)	6.2 ± 1.8 (305)	0.42	6.1 ± 1.5 (208)	6.1 ± 1.7 (749)	0.72
LH/FSH ratio	1.8 ± 1.1 (956)	1.7 ± 1.0 (760)	2.0 ± 1.6 (196)	0.014	1.7 ± 1.0 (747)	1.9 ± 1.6 (209)	0.043	1.7 ± 1.0 (651)	1.8 ± 1.4 (305)	0.22	1.9 ± 0.8 (207)	1.7 ± 1.2 (749)	0.038
Insulin -μIU/mL	13.8 ± 12.7 (957)	14.4 ± 13.1 (760)	11.8 ± 10.9 (197)	0.010	14.3 ± 12.9 (747)	12.3 ± 11.9 (210)	0.046	14.3 ± 12.9 (652)	12.7 ± 12.4 (305)	0.07	14.7 ± 10.8 (208)	13.6 ± 13.2 (749)	0.25
Glucose -mg/dL	91.5 ± 17.9 (958)	91.7 ± 18.4 (760)	90.7 ± 15.8 (198)	0.48	91.8 ± 18.4 (747)	90.6 ± 15.7 (211)	0.38	91.8 ± 18.5 (649)	90.9 ± 16.6 (309)	0.46	89.9 ± 15.7 (206)	92.0 ± 18.4 (752)	0.15
HOMA-IR	3.3 ± 3.6 (949)	3.4 ± 3.8 (755)	2.7 ± 2.8 (194)	0.013	3.4 ± 3.8 (742)	2.8 ± 3.1 (207)	0.043	3.4 ± 3.6 (647)	3.0 ± 3.7 (302)	0.09	3.3 ± 2.6 (206)	3.3 ± 3.9 (743)	0.91
Triglyceride	1.6 ± 0.9 (958)	1.6 ± 0.9 (760)	1.4 ± 0.8 (198)	< 0.001	1.6 ± 0.9 (747)	1.4 ± 0.8 (211)	< 0.001	1.6 ± 0.9 (650)	1.5 ± 0.9 (308)	0.017	1.7 ± 0.9 (207)	1.5 ± 0.9 (751)	0.09
Cholesterol	4.7 ± 1.1 (957)	4.8 ± 1.1 (759)	4.5 ± 1.0 (198)	0.002	4.8 ± 1.1 (746)	4.5 ± 1.0 (211)	< 0.001	4.8 ± 1.1 (649)	4.7 ± 1.0 (308)	0.08	4.9 ± 1.2 (207)	4.7 ± 1.1 (750)	0.08
LDL-C	3.0 ± 0.9 (957)	3.0 ± 0.9 (759)	2.8 ± 0.8 (198)	0.002	3.0 ± 0.9 (746)	2.8 ± 0.8 (211)	< 0.001	3.0 ± 0.9 (649)	2.9 ± 0.8 (308)	0.05	3.1 ± 1.0 (207)	2.9 ± 0.8 (750)	0.010
HDL-C	1.3 ± 0.4 (958)	1.3 ± 0.4 (760)	1.3 ± 0.4 (198)	0.51	1.3 ± 0.4 (747)	1.3 ± 0.4 (211)	0.73	1.3 ± 0.4 (649)	1.3 ± 0.4 (309)	0.14	1.2 ± 0.3 (207)	1.3 ± 0.4 (751)	0.034

Mean ± SD or n/N (%) values are presented. BMI, body mass index; LH, luteinizing hormone; FSH, follicle stimulating hormone; FAI, Free androgen index = T/SHBG × 100; HOMA-IR, homeostatic model assessment insulin resistance; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol

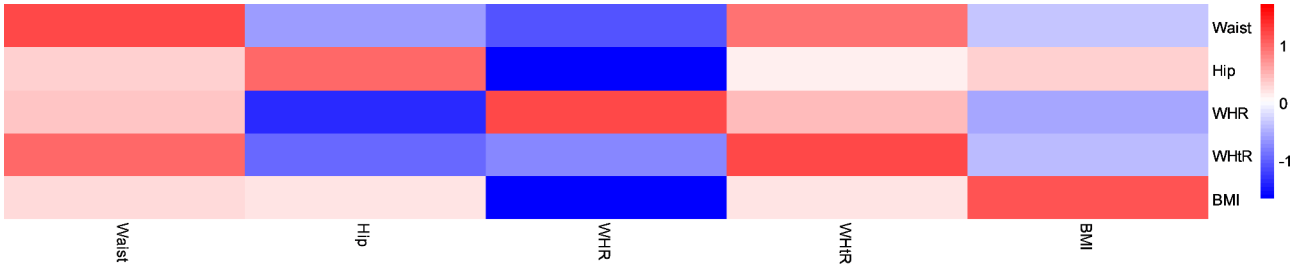

Fig. 1 Pearson correlation coefficient for obesity variables. Pearson correlation coefficient between obesity variables were calculated. BMI, body mass index; WHR, Waist/hip ratio; WHtR, Waist/height ratio

Table 2 Odd ratio and 95% confidence intervals for the risk of reproductive outcomes across quintiles of obesity variables

	Live birth		Pregnancy		Conception		Ovulation	
	Quintiles	OR(95%)	Quintiles	OR(95%)	Quintiles	OR(95%)	Quintiles	OR(95%)
Waist	1	Ref	1	Ref	1	Ref	1	Ref
	2	1.17(0.75,1.85)	2	1.16(0.74,1.81)	2	1.02(0.67,1.55)	2	1.41(0.80,2.49)
	3	0.81(0.51,1.29)	3	0.82(0.52,1.30)	3	0.86(0.57,1.30)	3	0.92(0.56,1.51)
	4	0.57(0.34,0.93)	4	0.55(0.34,0.90)	4	0.76(0.50,1.16)	4	0.68(0.42,1.11)
	5	0.57(0.34,0.94)	5	0.62(0.38,1.01)	5	0.64(0.42,1.00)	5	0.45(0.28,0.74)
	P-trend	0.013	P-trend	0.017	P-trend	0.23	P-trend	< 0.001
Hip	1	Ref	1	Ref	1	Ref	1	Ref
	2	1.02(0.64,1.63)	2	1.19(0.76,1.89)	2	1.04(0.69,1.57)	2	0.93(0.56,1.57)
	3	1.22(0.77,1.95)	3	1.29(0.81,2.06)	3	1.29(0.85,1.96)	3	0.83(0.49,1.40)
	4	0.75(0.44,1.28)	4	0.78(0.46,1.34)	4	0.87(0.55,1.38)	4	0.86(0.49,1.50)
	5	0.81(0.49,1.34)	5	0.93(0.57,1.53)	5	0.81(0.52,1.26)	5	0.40(0.24,0.66)
	P-trend	0.34	P-trend	0.31	P-trend	0.25	P-trend	< 0.001
Waist/hip ratio	1	Ref	1	Ref	1	Ref	1	Ref
	2	0.98(0.62,1.56)	2	0.94(0.59,1.48)	2	1.22(0.79,1.87)	2	1.21(0.70,2.11)
	3	0.61(0.38,0.97)	3	0.62(0.39,0.98)	3	0.83(0.55,1.26)	3	0.73(0.45,1.18)
	4	0.62(0.38,1.00)	4	0.64(0.40,1.02)	4	0.90(0.59,1.38)	4	1.02(0.61,1.72)
	5	0.42(0.25,0.71)	5	0.45(0.27,0.73)	5	0.57(0.36,0.88)	5	0.57(0.35,0.91)
	P-trend	0.004	P-trend	0.009	P-trend	0.020	P-trend	0.025
Waist/height	1	Ref	1	Ref	1	Ref	1	Ref
	2	1.13(0.72,1.79)	2	0.96(0.61,1.51)	2	0.94(0.62,1.43)	2	0.65(0.38,1.12)
	3	0.87(0.54,1.39)	3	0.48(0.28,0.82)	3	0.59(0.37,0.94)	3	0.64(0.36,1.15)
	4	0.64(0.39,1.06)	4	0.63(0.39,1.01)	4	0.81(0.53,1.24)	4	0.49(0.29,0.82)
	5	0.55(0.33,0.92)	5	0.60(0.36,0.98)	5	0.62(0.40,0.97)	5	0.34(0.20,0.58)
	P-trend	0.005	P-trend	0.018	P-trend	0.08	P-trend	0.001
BMI	1	Ref	1	Ref	1	Ref	1	Ref
	2	1.13(0.72,1.79)	2	1.26(0.80,1.97)	2	1.11(0.73,1.69)	2	0.97(0.55,1.70)
	3	0.84(0.53,1.35)	3	0.90(0.56,1.43)	3	0.82(0.54,1.26)	3	0.71(0.42,1.22)
	4	0.64(0.39,1.05)	4	0.67(0.41,1.10)	4	0.81(0.53,1.24)	4	0.64(0.38,1.09)
	5	0.54(0.33,0.91)	5	0.60(0.36,0.99)	5	0.57(0.37,0.89)	5	0.31(0.19,0.52)
	P-trend	0.030	P-trend	0.022	P-trend	0.040	P-trend	< 0.001

All analyses were adjusted for CC. For each obesity variable, the odd ratio and 95% confidence interval for a standard deviation higher level of the variable is shown, together with the *p*-value for the log-linearity of the association

$p<0.05$ for log-linear trend). Linear associations were noted among waist circumference, WHtR, the occurrence of live birth, pregnancy, and ovulation ($p<0.05$ for log-linear trend). However, only a linear association was noted between hip circumference and ovulation ($p<0.05$ for log-linear trend).

Prediction of different reproductive outcomes by obesity indices

We found that the BMI cut-off values of 33.76, 19, 19 and 28.7 maximized the height above the uninformative diagonal to the "perfect" point (0.226, 0.225, 0.266, 0.392) for predicting live birth, pregnancy, conception and ovulation, respectively, according to the AUC (Table 3). A WHR cut-off value of 0.78 maximized the height above

Table 3 Cutoff value of obesity variables, sensitivity, specificity and Youden index for the prediction of reproductive outcomes

	Model	Cutoff value	Sensitivity	Specificity	Youden index
Live birth	BMI	33.76	0.721	0.506	0.226
	Hip	89	0.727	0.48	0.207
	Waist	110	0.741	0.497	0.238
	WHtR	0.688	0.756	0.488	0.244
	WHR	0.78	0.727	0.528	0.255
	BMI + Waist	28.12/110	0.725	0.526	0.251
	BMI + WHR	27/0.941	0.662	0.590	0.252
	BMI + WHtR	20.77/0.44	0.725	0.509	0.235
	$BMI + BMI^2$	19	0.725	0.499	0.225
	$WHR + WHR^2$	0.951	0.717	0.545	0.262
Pregnancy	BMI	19	0.719	0.506	0.225
	Hip	85	0.683	0.527	0.21
	Waist	70	0.720	0.514	0.234
	WHtR	0.422	0.706	0.541	0.247
	WHR	0.78	0.729	0.527	0.256
	BMI + Waist	18.06/69	0.691	0.545	0.236
	BMI + WHR	27.67/0.97	0.705	0.559	0.264
	BMI + WHtR	18.4/0.436	0.710	0.536	0.246
	$BMI + BMI^2$	19	0.728	0.504	0.232
	$WHR + WHR^2$	0.78	0.739	0.518	0.256
Conception	BMI	19	0.727	0.538	0.266
	Hip	118	0.659	0.59	0.249
	Waist	89	0.709	0.552	0.261
	WHtR	0.422	0.706	0.571	0.277
	WHR	0.78	0.728	0.540	0.268
	BMI + Waist	19/70	0.727	0.538	0.266
	BMI + WHR	18.87/0.773	0.715	0.563	0.278
	BMI + WHtR	18.4/0.436	0.708	0.547	0.256
	$BMI + BMI^2$	19	0.727	0.538	0.266
	$WHR + WHR^2$	0.78	0.731	0.537	0.268
Ovulation	BMI	28.7	0.516	0.876	0.392
	Hip	74	0.578	0.803	0.381
	Waist	111.5	0.579	0.807	0.387
	WHtR	0.427	0.609	0.784	0.393
	WHR	0.99	0.563	0.817	0.379
	BMI + Waist	18.57/74	0.615	0.780	0.395
	BMI + WHR	17.97/0.81	0.605	0.789	0.394
	BMI + WHtR	28.73/0.608	0.517	0.876	0.393
	$BMI + BMI^2$	28.7	0.516 2	0.876	0.390
	$WHR + WHR^2$	1.038	0.579	0.803	0.382

All models were adjusted for age, CC and acupuncture

the uninformative diagonal for predicting live birth, pregnancy and conception (Table 3). For ovulation, a WHR cut-off of 0.99 maximized the height above the uninformative diagonal (0.379). Combined with those of the adipometric variables, the cut-off values for the WHR showed no significant differences for live birth, pregnancy, conception or ovulation. However, there was a significant difference in the cut-off values of BMI (alone or in combination) for live birth (Table 3).

We found that the differences in the delta likelihood ratio X^2 were in favour of a stronger association between the WHR and predicted live birth, pregnancy, BMI, conception, and ovulation when the models with indices of obesity and covariates were compared (Table 4). There was no significant interaction effect between obesity and CC in the models.

As assessed using Akaike's information criterion (AIC), we found that the model fit was the best with the WHR and the worst with the hip circumference included in the prediction models for live birth and pregnancy. Model performance with BMI + WHR was slightly greater than that with WHR alone when the adipometric variable was

Table 4 Area under the receiver operating characteristics curves (AUC) and 95% confidence interval, Akaike information criterion (AIC), difference in likelihood ratio chi-square (with model with covariates only) and p-value, and calibration chi-square and p-value for the prediction of reproductive outcomes

	Model	AUC	AIC	Delta likelihood ratio x2	Calibration x2
Live birth	BMI	0.631(0.590,0.672)	982.781	33.64(0.00)	7.81(0.45)
	Hip	0.615(0.573,0.657)	991.844	27.75(0.00)	5.41(0.71)
	Waist	0.637(0.596,0.677)	984.058	35.54(0.00)	15.78(0.05)
	WHtR	0.638(0.597,0.678)	984.381	35.21(0.00)	11.23(0.19)
	WHR	0.645(0.605,0.685)	979.650	39.94(0.00)	14.81(0.06)
	BMI + Waist	0.637(0.596,0.678)	982.889	35.54(0.00)	13.52(0.10)
	BMI + WHR	0.646(0.606,0.686)	977.455	40.97(0.00)	6.69(0.57)
	BMI + WHtR	0.637(0.597,0.678)	983.048	35.38(0.00)	13.00(0.11)
	BMI + BMI^2	0.632(0.591,0.673)	983.900	34.52(0.00)	9.88(0.27)
	WHR + WHR^2	0.652(0.612,0.692)	978.153	43.44(0.00)	13.63(0.09)
Pregnancy	BMI	0.631(0.591,0.671)	1015.165	35.53(0.00)	10.53(0.23)
	Hip	0.614(0.573,0.656)	1023.766	29.98(0.00)	7.07(0.53)
	Waist	0.635(0.595,0.675)	1017.204	36.54(0.00)	15.00(0.06)
	WHtR	0.636(0.596,0.676)	1017.784	35.96(0.00)	7.61(0.47)
	WHR	0.643(0.604,0.683)	1012.244	41.50(0.00)	10.20(0.25)
	BMI + Waist	0.635(0.595,0.675)	1016.042	36.66(0.00)	18.08(0.02)
	BMI + WHR	0.644(0.604,0.684)	1010.429	42.27(0.00)	16.04(0.04)
	BMI + WHtR	0.635(0.595,0.675)	1016.328	36.37(0.00)	14.52(0.07)
	BMI + BMI^2	0.635(0.595,0.675)	1015.617	37.08(0.00)	12.71(0.12)
	WHR + WHR^2	0.650(0.611,0.689)	1011.034	44.71(0.00)	9.87(0.27)
Conception	BMI	0.650(0.615,0.686)	1193.030	62.89(0.00)	7.31(0.50)
	Hip	0.636(0.600,0.673)	1202.460	55.73(0.00)	5.30(0.73)
	Waist	0.647(0.612,0.683)	1197.883	60.31(0.00)	10.07(0.26)
	WHtR	0.646(0.610,0.682)	1199.144	59.05(0.00)	4.89(0.77)
	WHR	0.651(0.615,0.686)	1196.263	61.93(0.00)	6.72(0.57)
	BMI + Waist	0.650(0.615,0.686)	1195.029	62.89(0.00)	7.30(0.50)
	BMI + WHR	0.653(0.618,0.688)	1192.651	65.27(0.00)	7.32(0.50)
	BMI + WHtR	0.650(0.615,0.686)	1194.876	63.04(0.00)	9.49(0.30)
	BMI + BMI^2	0.651(0.615,0.686)	1194.699	63.22(0.00)	7.79(0.45)
	WHR + WHR^2	0.652(0.616,0.687)	1197.169	63.02(0.00)	6.86(0.55)
Ovulation	BMI	0.741(0.706,0.776)	924.916	128.34(0.00)	6.53(0.59)
	Hip	0.725(0.688,0.761)	937.286	116.46(0.00)	4.92(0.77)
	Waist	0.729(0.693,0.764)	936.446	117.30(0.00)	8.78(0.36)
	WHtR	0.732(0.696,0.767)	934.008	119.74(0.00)	6.68(0.57)
	WHR	0.715(0.679,0.750)	946.967	106.78(0.00)	5.97(0.65)
	BMI + Waist	0.741(0.707,0.776)	926.396	128.86(0.00)	8.88(0.35)
	BMI + WHR	0.741(0.706,0.776)	926.859	128.39(0.00)	6.62(0.58)
	BMI + WHtR	0.741(0.706,0.776)	926.916	128.34(0.00)	5.65(0.69)
	BMI + BMI^2	0.741(0.706,0.776)	926.791	128.46(0.00)	6.89(0.55)
	WHR + WHR^2	0.714(0.679,0.750)	948.026	107.72(0.00)	6.00(0.65)

All models were adjusted for age, CC and acupuncture

added (Table 4). Among the prediction models, the performance of the model that included the BMI was the best, whereas that of the model that included the hip circumference was the worst. The BMI + WHR model performed slightly better than that with BMI alone. For predicting ovulation, the BMI model performed the best, and the WHR model performed the worst. The results of the models combining the adipometric variables (BMI + waist, BMI + WHtR and BMI + WHR) were the same but less than those of the model with BMI alone.

Based on AUC comparisons of the models for the prediction of live birth and pregnancy (Fig. 2; Tables 3 and 4), no significant differences were noted in the models with single adipometric variables except for the hip, but the models with other single adipometric variables performed better than the model with hip circumference. Furthermore, the models with a combination of

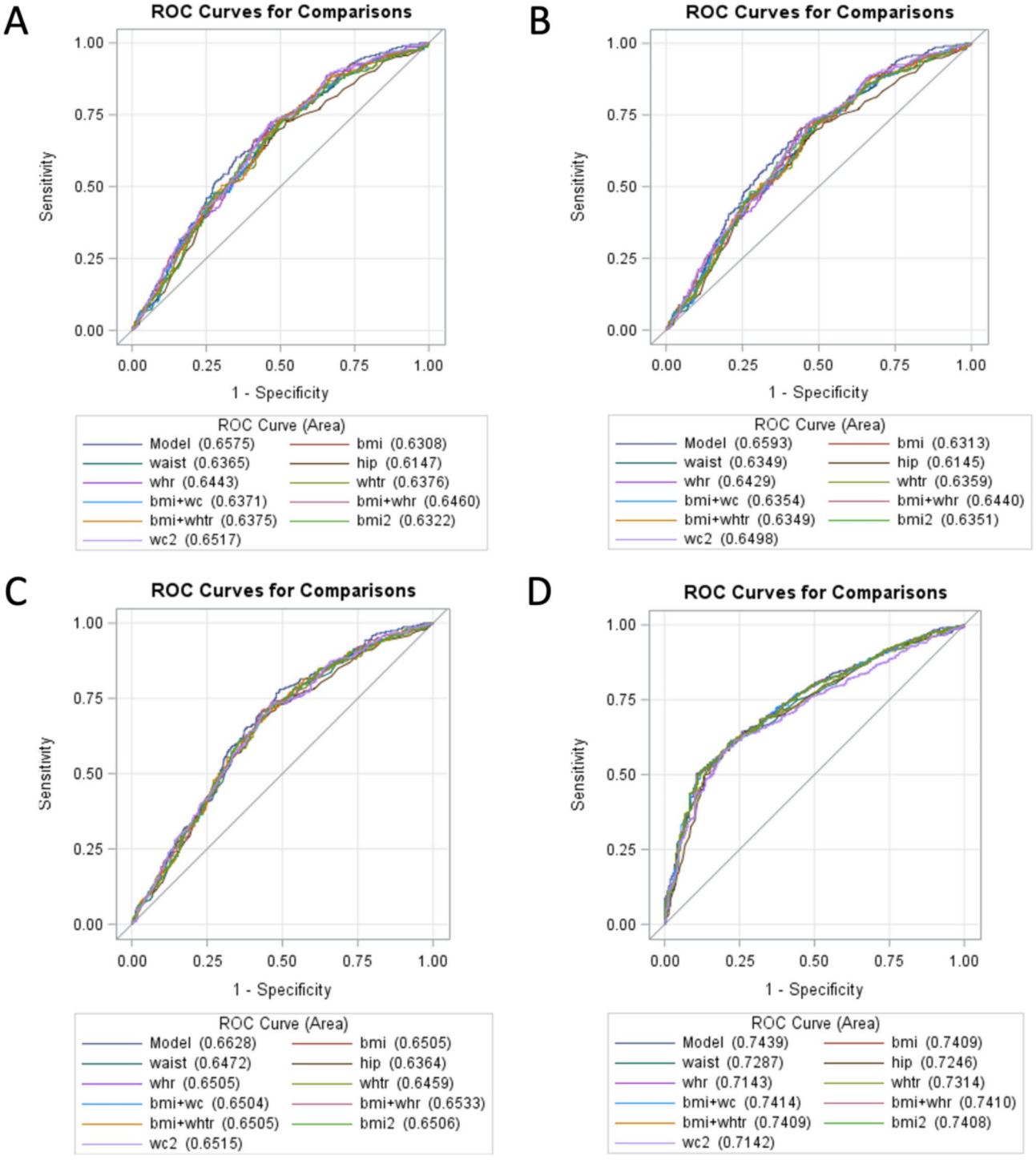

Fig. 2 Area under the receiver operating characteristics curves (AUC) for the prediction of reproductive outcomes. **A**: ROC for the prediction of live birth; **B**: ROC for the prediction of pregnancy; **C**: ROC for the prediction of conception; **D**: ROC for the prediction of ovulation

adipometric variables did not achieve better performance. According to the IDI statistic, the model with WHR alone was not better than the models with single adipometric variables. The models with combinations of BMI+WHR performed better than the models with the individual variables (BMI, waist and WHtR) or combinations of BMI+waist and BMI+WHtR. However, the model with BMI+WHR was the same as the model with WHR alone. Based on AUC comparisons of the prediction models, the models with hip circumference performed worse than the models with the other single adipometric variables and combinations of adipometric

variables. However, differences in the AUC values among the models with other adipometric variables were non-significant. According to the IDI statistic, the models with single adipometric variables were similar in performance to each other. The models with combinations of BMI+WHR performed better than the models with the individual variables (waist and WHtR). However, the model with BMI+WHR had the same performance as the model with BMI and WHR alone.

Based on AUC comparisons of the models for predicting ovulation, the models with BMI alone performed better than did the models with single adipometric variables (hip, waist and WHR) but not the model with WHtR. The performance of the models with a combination of adipometric variables was better than that of the models with single adipometric variables (hip, waist and WHR) but was similar to that of the models with single adipometric variables (BMI and WHtR). According to the IDI statistic, the models with combinations of BMI performed better than the models with the individual variables (waist, WHR and WHtR). Furthermore, the performance of the models that included a combination of anthropometric variables (BMI+waist, BMI+WHR and BMI+WHtR) was not better than that of the model that included BMI alone (Table 5).

Discussion

In this study, we developed multivariable models to compare adipometric variables for predicting reproductive outcomes in a large sample of Chinese PCOS women who received clomiphene (clomiphene or placebo) and acupuncture (active or control) for PCOSAct. Based on AUC comparisons and integrated discrimination improvement (IDI) analyses, we found that BMI was significantly superior to other adipometric variables for predicting ovulation in women with PCOS. Combining adipometric variables did not improve discriminatory ability beyond that of BMI alone for predicting ovulation but did significantly improve discriminatory ability over models including other single adipometric variables. For live birth, pregnancy and conception, the WHR was a better predictor in PCOS women, whereas BMI+WHR was more effective for these conditions. The model that included hip circumference was relatively weak for predicting reproductive outcomes.

BMI is used for assessing obesity, and the use of anthropometric measures, including WC, WHR, or WHtR, reflects abdominal obesity in clinical practice and public health in general. Notably, interobserver variability is one of the major drawbacks in anthropometric measurements. In addition, our study revealed that adipometric variables apart from hip circumference are clearly distinct and independently predictive of reproductive outcomes among PCOS women who received clomiphene (clomiphene or placebo) and acupuncture (active or control). Almost all of the adipometric variables show log-linear associations, with a higher level of each adipometric variable contributing to lower effect sizes. However, the associations with BMI or WHR were not stronger than those with other adipometric variables based on likelihood ratio comparisons. Although BMI and WHR have been shown to be good predictors of reproductive outcomes [18–21], models with BMI or WHR did not demonstrate a better degree of discrimination based on AUC comparisons. However, the IDI statistics were in favour of a significant advantage of models with BMI for predicting ovulation. Combining adipometric variables with BMI+WHR improved discrimination compared with models with single adipometric variables. Moreover, for live birth, pregnancy and conception, there was no significant advantage for models with a single adipometric variable based on IDI statistics, but there was a significant advantage for models with BMI+WHR compared with models with a single adipometric variable. In addition, our study revealed that women with lower SHBG, higher FAI, and higher insulin had worse reproduction. Evidence suggests that obesity is a significant risk factor in regard to predicting PCOS [8, 22–25]. Moreover, BMI and WHR, as proxy measures of obesity, have been demonstrated to be good predictors of reproductive outcomes in women with PCOS [23]. In the present study, BMI was used as a criterion for obesity, but BMI describes only total body mass and does not distinguish between fat and muscle [22, 23]. In addition, in addition to the degree of obesity, the location distribution of fat accumulation is considered an important indicator; in particular, abdominal obesity is related to metabolic dysfunction in women with PCOS [26, 27]. However, virtually no study has explored which is the better discriminator of prevalent screen-detected obesity or reproduction in women with PCOS. Because infertility represents an important health problem that imposes a significant burden on women with PCOS, detecting reproductive capacity in a timely fashion and allowing appropriate interventions, population-based screening and early treatment could reduce the burden associated with its diagnosis and implications. With the understanding of the best predictive risk tool for reproductive capacity in women with PCOS, awareness and management are more likely to be successful in the population with improved long-term outcomes.

The biological mechanisms underlying the effects of obesity on reproduction have been discussed previously and involve the hypothalamic–pituitary–ovarian axis and neuroendocrine systems [7]. Obesity can impact reproductive endocrine function, primarily through variations in the reactivity of sex hormones and their corresponding receptors. Obesity can act on

Table 5 Integrated discrimination improvement (IDI, %) statistic comparing models of the prediction for reproductive outcomes with adipometric variables with models for which the variable has been replaced by another adipometric variable or their combination

Variables	BMI	Waist	WHR	WHtR	BMI + Waist	BMI + WHR	BMI + WHtR	BMI + BMI^2	WHR + WHR^2
Live birth									
BMI	NA	0.18 (-0.21,0.55)	0.56 (-0.14,1.27)	0.14 (-0.25,0.53)	0.18 (-0.11,0.48)	0.68 (0.11,1.25)	0.16 (-0.13,0.45)	0.07 (-0.11,0.26)	0.60 (-0.09,0.99)
Waist		NA	0.4 (-0.09,0.89)	-0.04 (-0.20,0.12)	0.01 (-0.09,0.11)	0.50 (0.11,0.89)	-0.02 (-0.19,0.16)	-0.11 (-0.52,0.31)	0.26 (-0.10,0.62)
WHR			NA	-0.44 (-0.91,0.03)	-0.38 (-0.92,0.16)	0.12 (-0.13,0.37)	-0.40 (-0.94,0.14)	-0.49 (-1.22,0.23)	-0.13 (-0.72,0.45)
WHtR				NA	0.05 (-0.013,0.22)	0.54 (0.17,0.92)	0.02 (-0.10,0.15)	-0.07 (-0.50,0.36)	0.03 (-0.10,0.71)
BMI + Waist					NA	0.50 (0.09,0.90)	-0.02 (-0.14,0.10)	-0.11 (-0.45,0.22)	0.26 (-0.11,0.63)
BMI + WHR						NA	-0.52 (-0.91,-0.12)	-0.61 (-1.19,-0.03)	-0.23 (-0.71,0.25)
BMI + WHtR							NA	-0.09 (-0.42,0.24)	0.29 (-0.12,0.69)
BMI + BMI^2								NA	0.38 (-0.11,0.87)
Waist + $Waist^2$									NA
Pregnancy									
BMI	NA	0.09 (-0.24,0.43)	0.53 (-0.14, 1.20)	0.03 (-0.32,0.37)	0.11 (-0.11,0.34)	0.62 (0.09,1.16)	0.08 (-0.12,0.27)	0.13 (-0.13,0.39)	0.39 (-0.13,0.92)
Waist		NA	0.45 (-0.02,0.92)	-0.07 (-0.20,0.07)	0.02 (-0.11,0.15)	0.53 (0.15,0.91)	-0.02 (-0.20,0.17)	0.04 (-0.38,0.46)	0.29 (-0.09,0.68)
WHR			NA	-0.52 (-0.96,-0.07)	-0.42 (-0.95,0.11)	0.09 (-0.13,0.32)	-0.45 (-1.00,0.09)	0.40 (-1.11,0.31)	-0.16 (-0.73,0.42)
WHtR				NA	0.08 (-0.10,0.27)	0.60 (0.23,0.97)	0.05 (-0.12,0.23)	0.10 (-0.32,0.53)	0.36 (-0.06,0.78)
BMI + Waist					NA	0.51 (0.11,0.92)	-0.04 (-0.13,0.06)	0.02 (-0.31,0.35)	0.28 (-0.13,0.69)
BMI + WHR						NA	-0.55 (-0.96,-0.14)	-0.49 (-1.07,0.08)	-0.23 (-0.72,0.26)
BMI + WHtR							NA	0.06 (-0.26,0.37)	0.06 (-0.26,0.37)
BMI + BMI^2								NA	0.26 (-0.20,0.73)
Waist + $Waist^2$									NA
Conception									
BMI	NA	-0.22 (-0.56,0.12)	-0.09 (-0.69, 0.51)	-0.33 (-0.69,0.03)	-	0.21 (-0.10,0.53)	0.01 (-0.07,0.09)	0.04 (-0.07,0.15)	-0.11 (-0.51,0.28)
Waist		NA	0.14 (-0.23,0.51)	-0.11 (-0.23,0.01)	0.22 (-0.13,0.56)	0.43 (0.14,0.72)	0.23 (-0.18,0.63)	0.25 (-0.11,0.62)	0.10 (-0.11,0.31)
WHR			NA	-0.25 (-0.06,0.01)	0.09 (-0.51,0.69)	0.30 (-0.09,0.68)	0.10 (-0.55,0.75)	0.12 (-0.49,0.74)	-0.04 (-0.45,0.37)
WHtR				NA	0.33 (-0.03,0.69)	0.54 (0.22,0.86)	0.34 (-0.08,0.76)	0.37 (-0.01,0.75)	0.21 (-0.04,0.46)
BMI + Waist					NA	0.21 (-0.11,0.53)	0.01 (-0.07,0.09)	0.04 (-0.07,0.15)	-0.11 (-0.51,0.29)
BMI + WHR						NA	-0.20 (-0.58,0.18)	-0.17 (-0.50,0.15)	-0.32 (-0.66,0.01)
BMI + WHtR							NA	0.03 (-0.11,0.17)	0.03 (-0.11,0.17)
BMI + BMI^2								NA	-0.15 (-0.53,0.23)
Waist + $Waist^2$									NA
Ovulation									

Table 5 (continued)

Variables	BMI	Waist	WHR	WHtR	BMI + Waist	BMI + WHR	BMI + WHtR	BMI + BMI^2	WHR + WHR^2
BMI	NA	-1.21 (-1.88,-0. 54)	-2.33 (-3.46,-1.19)	-0.94 (-1.64,-0. 23)	0.06 (-0.10,0.22)	0.01 (-0.04,0.07)	-	< 0.001 (-0.08, 0.09)	-1.21 (-1.88,-0.54)
Waist		NA	-1.11 (-1.77,-0. 45)	0.27 (0.01,0. 53)	1.27 (0.48, 2.06)	1.23 (0.52, 1.93)	1.21 (0.54, 1.88)	1.22 (0.55,1.88)	0 (-0.05,0.06)
WHR			NA	1.38 (0. 67, 2.09)	2.38 (1.20, 3.57)	2.34 (1.19,3.49)	2.33 (1.19,3.46)	2.33 (1.21,3.44)	1.11 (0.44,1.78)
WHtR				NA	1.00 (0. 17, 1.82)	0.95 (0. 21,1.69)	0.94 (0.23, 1.65)	0.94 (0.24,1.64)	-0.27 (-0.54,<0.001)
BMI + Waist					NA	-0.05 (-0.17,0.08)	-0.06 (-0.22,0.10)	-0.06 (-0.23,0.12)	-1.27 (-2.06,-0.48)
BMI + WHR						NA	-0.01 (-0.07,0.04)	-0.01 (-0.11,0.09)	-1.22 (-1.92,-0.53)
BMI + WHtR							NA	0 (-0.08,0.09)	0 (-0.08,0.09)
BMI + BMI^2								NA	-1.21 (-1.88,-0.54)
Waist + $Waist^2$									NA

All models were adjusted for age, CC and acupuncture. BMI, body mass index; WHR, Waist/hip ratio; WHtR, Waist/height ratio

the hypothalamic–pituitary–ovarian axis via inflammatory cytokines and oxidative stress and lead to increased serum insulin and androgen levels [28–30]. Obesity can cause a considerable amount of free fatty acids to accumulate in ovaries, causing damage to the cell membrane, mitochondria and lysosome [31–33]. Obesity, alone or combined with hyperandrogenism, polycystic ovarian morphology, oligoanovulatory ovarian dysfunction and hyperinsulinaemic insulin resistance, could determine whether abnormalities in oocyte competence and oocyte quality contribute to PCOS-related subfertility [34, 35]. Obesity promotes IR and hyperinsulinaemia, hyperandrogenism, and low-grade inflammation, which not only reduces endometrial receptivity but also contributes to an increased risk of pregnancy complications in women with PCOS [36–38].

This study had several strengths. Our results were obtained from 21 sites (27 hospitals) in mainland China with wide coverage, a relatively large representative sample, and direct measurements of anthropometrics. In this study, both routine and advanced analytic techniques are used to investigate the associations and compare the predictive values. However, a major limitation is that all PCOS women were recruited from China and received clomiphene (clomiphene or placebo) and acupuncture (active or control) for the treatment of PCOS.

In summary, our study in a Chinese PCOS population with clomiphene (clomiphene or placebo) and acupuncture (active or control) suggested that BMI is a better predictor of ovulation and that WHR is a better predictor of live birth, pregnancy and conception. However, different adipometric variables are significant predictors. The combination of adipometric variables added to the discrimination of reproduction. Our findings support the applicability of current recommendations for improving the prediction of screen-detected reproduction in this population of Chinese women with PCOS. These findings emphasize the greater importance of BMI and the WHR for PCOS.

Abbreviations

BMI	Body mass index
PCOS	Polycystic ovary syndrome
SHBG	Sex hormone-binding globulin
WC	Waist circumference
WHR	Waist–hip-ratio
VAT	Visceral adipose tissue
CVD	Cardiovascular disease
WHtR	Waist– height-ratio
AUC	Area under the receiver operating characteristic curves
IDI	Iintegrated discrimination improvement
AIC	Akaike's Information Criterion

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Author contributions

XW proposed and designed the study. QX and LX conducted the statistical analysis. QW, JF and HH completed the literature search and data extraction. QX and LX drafted the first version of the manuscript. WC, JL, JC, HM and LJ participated in the critical revision of the manuscript. All authors reviewed and approved the final version of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of First Affiliated Hospital, Heilongjiang University of Chinese Medicine (2010HZYLL-010) and all patients provided written informed consents.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Conflict of interest
The authors declared no conflict of interest.

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