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Clinical characteristics, metabolic features, and phenotype of Chinese women with polycystic ovary syndrome: a large-scale case–control study

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Abstract
Aim The Rotterdam criteria extend the phenotypic spectrum of polycystic ovary syndrome (PCOS). The study was to investigate the clinical and biochemical features of a large-scale clinic based on the samples of Chinese women and to evaluate the value of Rotterdam criteria on Chinese PCOS women.
Methods One thousand four hundred and four Chinese women were involved in our study, among whom, 719 cases were diagnosed as PCOS based on 2003 Rotterdam criteria, and 685 women without history of hyperandrogenism and with regular menstrual cycles were recruited as control. Clinical features, ultrasonographic (ovarian follicle number and volume), hormonal and metabolic parameters were commenced as outcome measures.
Results Among 719 PCOS women, 6.1 % had hirsutism, 13.3 % had acne, 21.1 % had hyperandrogenism, 94.2 % had polycystic ovaries on ultrasonographic examination, and 88.6 % had menstrual abnormality. About one-third of the total PCOS patients were insulin resistant. The most frequent PCOS phenotype is the non-hyperandrogenic phenotype (O + P). Total testosterone, LH/FSH ratio, body mass index (BMI), and Ferriman and Gallwey scores (F–G) were all significantly higher in PCOS groups compared with non-PCOS group. Women with PCOS and obesity had higher serum testosterone, fasting insulin, longer menstrual cycle and larger ovarian follicle number, and LH/FSH ratio, estradiol or ovarian volume were similar between obese and normal BMI women. The LH level was statistically lower in the obese PCOS group.
Conclusions Rotterdam criteria are generally applicable to Chinese population. Chinese women with PCOS showed lower rates of hyperandrogenemia, hirsutism, obesity, and insulin resistance. Obesity aggravates menstrual irregularity and increases the follicle number and serum total testosterone level.

Keywords Chinese women · Diagnostic criteria · Obesity · Phenotype · Polycystic ovary syndrome

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Introduction

The polycystic ovary syndrome (PCOS) has been considered to be the most common endocrinopathy in women of reproductive age, with a prevalence of up to 10 % [1]. It is characterized by hyperandrogenism and chronic anovulation, and if remained undiagnosed or not treated properly, cardiovascular dysfunction, and metabolic disturbances such as hyperinsulinemia, type 2 diabetes mellitus may ensue in long-term [2, 3]. Women with PCOS demonstrate marked clinical heterogeneity; the commonly associated features such as hirsutism, acne, polycystic-appearing ovaries, obesity, and acanthosis nigricans are neither uniform nor universal [4, 5].

Based on 1990 NIH meeting criteria, two principal phenotypes are generally recognized: women with anovulation in conjunction with either biochemical or clinical hyperandrogenism [6]. Most participants of this meeting advocated that the presence of polycystic ovaries by

ultrasound (PCO-US) was suggestive, but not diagnostic for PCOS. Consequently, another expert conference was held in Rotterdam in 2003, recommending that PCOS be defined when at least two of the following three features were present: (i) oligo- and/or anovulation (O), (ii) clinical and/or biochemical signs of hyperandrogenism (H), and (iii) polycystic ovaries (P) and exclusion of other identifiable endocrine disorders such as late-onset congenital adrenal hyperplasia (CAH), hyperprolactinemia, thyroid dysfunction, neoplastic androgen secretion, or drug-induced androgen excess [7]. Given this new PCOS definition, four clinical subtypes of PCOS cases become identifiable. Whether oligo-anovulatory + polycystic ovaries without evidence of hyperandrogenism should be considered as PCOS is currently on debate [8, 9].

The clinical and biochemical features of PCOS may differ between different ethnics. For example, in comparative studies, the rate of hirsutism in Japanese patients was lower than that in Hispanic and Italian women living in the United States. The Ferriman–Gallwey (F–G) score was higher among South Asian patients living in the United Kingdom, compared with PCOS women of European descent living in the same locale. In previous studies, the rates of impaired glucose tolerance and non-insulin-dependent diabetes mellitus in Chinese women with PCOS were 20.5 and 1.9 %, respectively [10], while the prevalence in American women with PCOS was 31 and 7.5 %, respectively [11].

As there are significant ethnic and racial variations in the clinical presentation of PCOS, the current study was undertaken to (1) analyze certain clinical features of a large-scale of Chinese women with PCOS, (2) identify the phenotypes based on Rotterdam criteria in Chinese women with PCOS, (3) compare the clinical and biochemical characteristics of PCOS patients with normal women and, especially, among PCOS women with obesity and normal body mass index (BMI).

Materials and methods

Subjects

Seven hundred and nineteen cases were diagnosed as PCOS according to the Rotterdam's criteria [5]. None of these subjects were postmenopausal. None of them received oral contraceptives or other drugs, which may disturb the hormonal and metabolic equilibrium at least 3 months before the commencement of this study. The diagnosis of PCOS was also excluded in women with persistent elevations of prolactin (PRL) (>24 μg/L) or abnormal thyrotropin (TSH) values (>5.5 mIU/L or <0.35 mIU/L).

Control subjects were selected from women aged 18–45 years, who had regular menses, no hirsutism and accepted an annual examination during the same period as the PCOS subjects. An attempt was made to mimic the BMI distribution of the general population. 685 subjects with matching data in control group were compared with the PCOS subjects. None of them received oral contraceptives or other drugs that could interfere with the hormonal and metabolic equilibrium at least 3 months before the commencement of this study. None of them suffered from chronic or acute disease, and all were euthyroid according to the clinical evaluation. We excluded menopausal (including natural and surgical menopause) and women who were pregnant during the period of the evaluation.

This study was based on routine clinical practice. Institutional review board approval was obtained for this study, and informed consent was obtained from individuals who participated in this study.

Methods

Clinical assessment

Personal medical history was obtained from every woman according to a customized questionnaire. Menstrual cycle history was carefully assessed and included a general review since menarche and a detailed recall of the previous 2- to 3-year interval. Ovulatory dysfunction was defined as less than eight cycles per year, or menstrual cycle less than 26 days or more than 35 days in length. Physical examination was performed individually by two doctors. BMI was defined as body weight in kilograms divided by body height in meters squared (kg/m^2). Obesity was defined as BMI $\geq$ 25 kg/m^2, according to the Asia–Pacific definition [12]. Cases with Ferriman and Gallwey score $\geq$6 (F–G, $\geq$6) were considered as hirsutism [13]. Patients suspected of having excess androgen manifestated hirsutism and/or acne. Biochemical hyperandrogenemia was defined as circulating total testosterone (TT) levels above the 95th percentile (0.53 ng/mL) of the levels detected in the group of women who had no clinical evidence of hyperandrogenism or menstrual disturbances, and neither taking hormonal medication nor had a previous oophorectomy and/or hysterectomy.

Transvaginal ultrasound (LogIQ200 Pro series ultrasonic machine, Ge Company, Niskayuna, NY) was used to detect polycystic ovaries, which was defined as the presence of at least 1 ovary >10 mL or at least 12 follicles with 2–9 mm in diameter.

Congenital adrenal hyperplasia, non-classical 21-hydroxylase deficiency, hyperprolactinemia, Cushing's disease,

and androgen-secreting ovarian/adrenal tumors were excluded if suspected clinically.

Laboratory tests

The fasting blood serum hormone levels were obtained during day 2–6 of the menstrual cycles (natural or bleeding after progestin withdrawal). Serum sex hormones including follicle-stimulating hormone (FSH), luteotrophic hormone (LH), testosterone (T), and estradiol (E_2), were detected by chemiluminescence immunization (Beckman Access Health Company, Chaska, MN).

Blood samples were collected for fasting insulin and fasting glucose detection. The level of insulin resistance was calculated with the homeostasis model assessment (HOMA), which was calculated according to the formula: [plasma glucose (mmol/L) × insulin (μU/mL)]/22.5 [14]. Insulin resistance was defined by HOMA-IR level higher than the 95th percentile (≥1.66) for the normal women we studied. Additionally, serum PRL, TSH, and 17-hydroxyprogesterone levels were detected in blood samples of women with oligomenorrhea to exclude other causes of menstrual disorders. All subjects with elevated screening 17-OHP level (>6.36 nmol/L) were underwent an acute adrenocorticotrophic hormone (ACTH) stimulation test to exclude non-classic adrenal hyperplasia (NCAH).

Statistical analysis

Statistical analysis was performed by the Statistical Package for the Social Sciences, version 13.0, for Windows (SPSS, Inc., Chicago). Laboratorial and clinical data were compared between groups using analysis of covariance (ANCOVA) to control for BMI. Data are presented as mean ± SD. Student's *t* test was used for the comparison of continuous variables. Categorical variables were compared using Chi-square tests. Statistical significance was considered when two-tailed $P \leq 0.05$.

Results

The proportion of the main clinical characteristics of the 719 PCOS patients is shown in Table 1. The presence of menstrual disorder was 86.6 %, among which the adult patients could be traced back to their adolescent menarche. Of all the PCOS patients enrolled in this study, there were only 7.6 % without polycystic ovarian morphology. Patients with biochemical and clinical hyperandrogenism were 24.1 and 23.7 %, respectively. About one-third of the total PCOS patients were insulin resistant. Additionally, in PCOS group, the percentage of cases with obesity, ovarian volume ≥10 mL, and LH/FSH ratio ≥2 were 28.1, 53.7, and 20.8 %, respectively.

In PCOS group, the largest phenotype subclass included women with two features, oligomenorrhea and polycystic ovarians on ultrasound, namely O + P (52.2 %, Fig. 1). Only 7.6 % of the group satisfied the NIH criteria (O + H) but did not meet the criteria for PCO-US. Another 13.4 % had H + P (ovulatory phenotype), and 26.8 % had all the three features, namely O + H + P. The O + P and H + P subgroups represent the newer phenotypes according to the Rotterdam criteria.

A total of 1,404 women (719 PCOS and 685 control) were initially screened. These two groups were compared in terms of various biochemical markers and several demographic characteristics, as illustrated in Table 2. The results show that the mean age was similar between the two groups (27.54 ± 3.28 vs. 26.56 ± 3.25). Women with PCOS showed higher levels of TT, increased ovarian volume and ovarian follicle numbers, longer menstrual cycle, and rate of acne, that is accordance with the definition of PCOS based on the Rotterdam criteria. tLH/FSH ratio ($P < 0.05$), BMI ($P < 0.01$), and F–G scores ($P < 0.05$) in

Table 1 The proportion of clinical characteristics of the studied PCOS patients

	No. of cases	Percentage of patients
Polycystic ovaries	664	92.4
Oligo-anovulation	622	86.6
Hyperandrogenism	173	24.1
Hirsutism (F–G ≥6)	58	8.1
Acne	112	15.6
Ovarian volume ≥10 mL	386	53.7
Obesity (BMI ≥25)	263	36.6
LH/FSH ratio ≥2	150	20.8
Insulin resistance	203	28.2

F–G Ferriman and Gallwey score, *BMI* body mass index, *LH* luteinizing hormone, *FSH* follicle-stimulating hormone

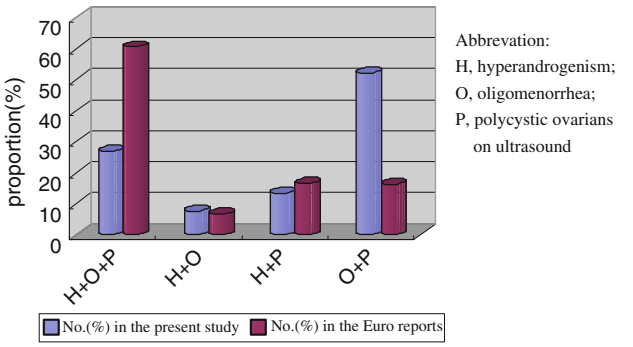

Fig. 1 The phenotype of PCOS and the proportion

Table 2 Clinical characteristics between PCOS and the control group

Characteristic	Patients	Controls
No. of cases	719	685
Age, years	27.54 ± 3.28	26.56 ± 3.25
BMI (kg/m^2)	23.67 ± 3.57*	21.63 ± 2.49
LH (mIU/mL)	10.58 ± 3.76*	5.13 ± 1.45
FSH (mIU/mL)	6.37 ± 2.13	6.28 ± 2.51
LH/FSH ratio	1.62 ± 0.89*	0.67 ± 0.26
T (ng/mL)	0.69 ± 0.34*	0.36 ± 0.17
E_2 (pg/mL)	48.8 ± 3.4	54.5 ± 1.8
FI (μU/mL)	14.3 ± 1.6	12.2 ± 6.3
Ovary volume (mL)	13.5 ± 4.83*	5.49 ± 2.97
Follicle count	12.1 ± 2.9*	8.5 ± 3.4
F–G score	7.3 ± 4.1*	3.6 ± 1.5
Acne (%)	13.3	3.2
Menstrual cycle length (median)	56 (47–117)	28 (25–31)

Student *t* test was used to compare the two groups of continuous variables. Categorical variables were compared using Chi-square tests

BMI body mass index, *LH* luteinizing hormone, *FSH* follicle-stimulating hormone, *T* testosterone, E_2 estradiol, *FI* fasting insulin, *F–G* Ferriman and Gallwey score

* $P < 0.05$ for PCOS group versus control group

* $P < 0.01$ for PCOS group versus control group

Table 3 Clinical and biochemical presentation of obese and non-obese PCOS groups

Characteristic	PCOS	
	Obese	Non-obese
No. of cases	263	446
Age, years	27.04 ± 3.4	27.38 ± 3.36
LH (mIU/mL)	8.16 ± 5.41	14.9 ± 5.98*
FSH (mIU/mL)	6.73 ± 2.35	5.98 ± 2.12
LH/FSH	1.53 ± 0.84	1.63 ± 1.02
E_2 (pg/mL)	50.94 ± 26.98	47.57 ± 27.31
T (ng/mL)	0.79 ± 0.25	0.58 ± 0.26*
FI (μU/mL)	15.54 ± 8.24	8.42 ± 5.23*
HOMA-IR	5.79 ± 3.21	3.52 ± 2.16*
Ovary volume	13.48 ± 5.84	13.61 ± 5.15
Insulin resistance	168	95
Abnormal FG (No. %)	7.1	1.5
Menstrual cycle (days) (median)	78 (45–117)	53 (41–64)
Follicle number (median)	20 (13–26)	15 (13–17)

Values are presented as mean ± SD or median values

Student *t* test was used to compare the two groups

LH luteinizing hormone, *FSH* follicle-stimulating hormone, E_2 estradiol, *T* testosterone, *FI* fasting insulin, *HOMA* homeostasis model assessment, *IR* insulin resistance

* $P < 0.05$ for non-obesity PCOS group versus obesity PCOS group

* $P < 0.01$ for non-obesity PCOS group versus obesity PCOS group

PCOS group were all significantly higher, compared with those in non-PCOS group. There were no differences between the groups with regard to fasting insulin (FI) and estradiol (E_2).

Table 3 shows two subgroups of PCOS patients divided based on the BMI, obesity, and non-obesity PCOS. For the normal women in our study, the upper control 95th percentile values for HOMA-IR were calculated as 2.52. Based on World Health Organization Asian criteria, the prevalence of obesity (BMI $\geq$ 25 kg/m^2) was 36.6 % (263/719). Only 6.7 % of these obesity women had a BMI higher than 30. Women with obesity achieved significantly ($P < 0.05$) higher serum testosterone, fasting insulin, HOMA-IR, longer menstrual cycle, and larger ovarian follicle number compared with non-obese women (BMI 18.5–24.9 kg/m^2). However, the results showed that the LH level in non-obese PCOS group was statistically higher than that in obesity PCOS group ($P < 0.01$). Additionally, there were no statistical differences between the two groups in LH/FSH ratio, serum estradiol, and ovarian volume as shown in Table 3.

Discussion

Polycystic ovary syndrome is believed to be one of the most common endocrine disorders in women, and a variety of studies regarding its clinical characteristics in Chinese women have been reported. Liou et al. [15] conducted their study with 464 Chinese PCOS women from Taiwan and Lin et al. [16] reported a sample of 192 Chinese PCOS women. This study includes a large-scale sample of 719 PCOS women who are all from Chinese Han population diagnosed based on the Rotterdam criteria of 2003, and with 685 normal women as the control group. The population we studied was homogeneous with regard to racial and ethnic variations and we have attempted to minimize selection bias in the inclusion of participants in this study.

The clinical manifestation of PCOS can vary greatly from patient to patient, and because of differences in ethnicity, the clinical characteristics and biochemical features of Chinese PCOS patients may differ from those of other races. Therefore, this study was performed to investigate the clinical and biochemical features of a large-scale sample of Chinese women with PCOS, to evaluate the value of 2003 Rotterdam criteria on Chinese PCOS women and to explore an appropriate diagnostic criterion for Chinese PCOS patients.

Based on the results of the present study, of the 719 PCOS patients, 247 (34.4 %) met both the diagnostic criteria of NIH 1990 and ESHRE/ASRM 2003, and the

proportion of new phenotypes created by the ESHRE/ASRM 2003 was 65.6 %. Our results were different from the study [17], which found that about 63 % of Hong Kong women with PCOS diagnosed by the 2003 Rotterdam criteria met the 1990 NIH diagnostic criteria. Our results were also different from those of the study reported by Diamanti-Kandarakis and Panidis [18], who found that of the 634 PCOS patients enrolled based on the ESHRE/ASRM criteria, about 85.96 % satisfied both the two diagnosis criteria, and only 14.04 % were the two new phenotypes. The reason might be that the culture and lifestyle in Hong Kong are more similar to those in Europe. Therefore, our study showed that the Rotterdam diagnostic criteria are generally more applicable to the population of China.

On estimating the prevalence of PCOS in our study, clinical hyperandrogenism (HA) was defined by the presence of hirsutism and/or acne. As the optimum system for acne scoring remains highly disputable [19], we selected to record its presence without grade in our subjects. In our study, 343 (47.8 %) PCOS women had HA, 24.1 % (173/719) had elevated total serum T levels, 23.7 % (170/719) had clinical HA with hirsutism and/or acne. Our results were different from the observations of the study [14] that had shown a higher prevalence of HA (78 %) in 295 Taiwan women with PCOS, of which 46 % had biochemical HA, 54 % had clinical HA. The prevalence of menstrual dysfunction in PCOS women in our study was 86.6 %, which is consistent with a previous report that, 94.1 % of 273 Chinese PCOS women presented with menstrual disturbances [20], and is also similar to the studies of PCOS in Greece, Spain and the USA [3, 21].

The F–G grade of hirsutism was significantly higher in PCOS population than the control group in our study, but only 5.1 % of the participants met the F–G score criterion of 6 in our data and the mean F–G scores were lower than those in Spain and the United States [22, 23]. The prevalence of hirsutism in PCOS varies according to ethnicity. In our study, the mean F–G score of PCOS group and the control group was 5.56 and 3.38, respectively. Of PCOS patients, the prevalence of cases whose F–G score was greater than the mean value of the control group was 97.2 %. And this result was significantly higher than the proportion that met the criterion of "Western" definition of 6. Thus, it may be necessary to consider the ethnic difference in the criteria for hirsutism. Future studies are required to confirm these data by recruiting more Chinese patients to make a compatible criterion of hirsutism for Chinese women.

Polycystic ovary morphology (PCOM) is an ultrasound criterion in the definition of PCOS which was added in the criteria of PCOS in 2003. The criteria of PCOM include the ovarian volume and the follicle number. PCOM is identified by pelvic or abdominal ultrasound and defined as $\geq$12 follicles in either ovary measuring 2–9 mm in diameter and/or increased ovarian volume >10 mL [24]. The prevalence of PCOM has been suggested to be higher than 20 % in both Western and Asian women [25, 26] and is the most frequently used criterion in PCOS diagnosis [27]. Our results showed that 94.2 % of the patients diagnosed based on the Rotterdam's criteria had polycystic ovaries, which is consistent with the data reported in the European studies (90–95 %) [18].

Obesity, insulin resistance, and hyperinsulinemia are strongly associated with PCOS [28, 29]. The results in the present study showed that the proportion of obesity and insulin resistance in PCOS patients were 36.6 and 28.2 %, respectively, and 68.4 % of those were central obesity. These data were all lower than those reported in some European studies, which probably was because of the differences of racial and living style, resulting in different criteria to evaluate obesity. As an important metabolic feature of PCOS, insulin resistance can be present in both obese and non-obese women with PCOS [30], but obesity can aggravate the insulin resistance. Our study findings are in good agreement with the study [31], which found that prevalence of insulin resistance in obese was significantly higher than that in non-obese women with PCOS. Moreover, indexes of insulin resistance, HOMA-IR, were significantly correlated to BMI. Additionally, our study showed that the extent of menstrual disorder and ovarian follicle numbers were both significantly higher in the obese PCOS patients than those in the non-obese group. The results showed that obesity would increase the severity of insulin resistance and appeared to exert an additive, synergistic impact on the manifestations of PCOS, independently and negatively affecting insulin sensitivity, risk of diabetes, and reproduction action [32, 33].

Elevated serum concentrations of LH are common in women with PCOS [34]. In this study, there was a significant difference in the serum LH levels between the overweight and normal weight PCOS women. The serum LH levels tended to decrease with increasing weight in the PCOS patients. This finding is in accordance with those of previous studies that have shown an inverse relationship between LH and BMI [35, 36].

Mean ovarian volume was statistically larger in PCOS patients than control group, but there was no significant difference between the non-obese and obese PCOS women. The absence of this expected difference could be partly attributable to the degree of LH and insulin observed in the non-obese and obese PCOS groups, because the former had higher LH level while the latter had greater fasting and stimulated insulin levels. Although ovarian size has been shown to be largely dependent on LH, insulin has also been found to contribute to ovarian volume [37].

In conclusion, our findings indicate that by applying the new criteria for PCOS according to the Rotterdam

consensus, the probability of diagnosis of the syndrome increases remarkably. Compared with the western PCOS women, Chinese women with PCOS showed lower rates of hyperandrogenemia, hirsutism, obesity, and insulin resistance, similar rates of PCO and menstrual irregularity. The Rotterdam diagnostic criteria for PCOS other than NIH criteria is generally more applicable to Chinese population, because there are only half of our patients with PCOS have clinical or biochemical hyperandrogenism. Obesity caused more severe menstrual irregularity and insulin resistance, and maybe had significantly impact on the long-term health risks and reproduction action of PCOS women.

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Conflict of interest We declare that we have no conflicts of interests.

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