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Hormone changes during the menstrual cycle of Chinese women

Liu Shi-fan*, Wang Zhong-xing*, Yuan Yao-e†, Bing Sheng-min†, Zhang Bei-zhu‡, Wu Jin-zhi‡, Wu Yi-e§ and Peng Xin-ying§

**Shanghai Institute of Planned Parenthood Research, 2200 Xie Tu Road, Shanghai; †Obstetrical and Gynaecological Hospital of Shanghai 1st Medical College, 419 Fang Xie Road, Shanghai; ‡International Peace Maternal and Childhood Hospital, 910 Heng Shan Road, Shanghai and §Shanghai Rui Jin Hospital, 197 Rui Jin Road, Shanghai, China*

Summary. The concentrations of LH, FSH, prolactin, oestradiol and progesterone in serum were measured daily during the menstrual cycle of 100 normal Chinese women. The cyclic changes in LH, FSH, oestradiol and progesterone were typical of ovulatory cycles in women of other ethnic groups as reported in the literature. The geometric mean of the LH midcycle peak value was 51·64 i.u./l, the FSH mid-cycle peak value was 11·52 i.u./l, the preovulatory oestradiol peak was 1229·12 pmol/l, and the progesterone luteal maximum was 53·27 nmol/l. The cyclic changes of prolactin concentrations were irregular: the value at mid-cycle was significantly higher than that at the follicular or luteal phases.

A correlation between the length of the cycle and mean concentrations of LH and oestradiol at different stages throughout the cycle was shown.

Introduction

During the past decade, many studies have been reported on the changes of LH, FSH, oestradiol and progesterone concentrations in circulating blood during the menstrual cycle of normal women. Among these studies, those of Diczfalusy & Landgren (1977) and Landgren, Unden & Diczfalusy (1980) were particularly extensive.

The purpose of the present study was to investigate systematically the profile of pituitary and ovarian hormone changes during the menstrual cycle of 100 normal Chinese women in Shanghai. Radioimmunoassay of daily serum levels of LH, FSH, prolactin, oestradiol and progesterone would provide basic information on the limits of normal values in China. These data are not only very important for understanding the mechanism of hormonal action and the assessment of various fertility regulating agents, but may also be valuable for the diagnosis of some gynaecological diseases. For example, Bing *et al.* (1982) have shown that such data could be used as a diagnostic index of climacterium. Wu *et al.* (1982) have also indicated such data might be helpful for the diagnosis of secondary amenorrhoea.

Materials and Methods

Volunteers

The criteria for the inclusion of volunteers were as follows: the women had to be apparently healthy and aged 19–35 years; the last 3 menstrual cycles had to be regular with a cycle length of 26–35 days; no steroid contraceptives or intrauterine devices had been used within 3 months; no

abortion had been induced within 6 months; and no delivery had occurred within 1 year before recruitment.

Calculation of cycle days

A cycle was calculated from the first day of menstrual bleeding (included), to the first day of next bleeding (excluded). The day of the midcycle LH surge was designated as Day LH 0. The length of the follicular phase was calculated from the first day of menstruation (included) to the day of the midcycle LH surge (included), whereas the luteal phase was defined as the period including the first day after the LH surge (Day LH + 1), but excluding the day of the onset of the next menstruation. The phases were further divided into the early follicular phase (before Day LH − 7), the late follicular phase (Day LH − 7 to Day LH − 3); the early luteal phase (Day LH + 3 to Day LH + 7) and the late luteal phase (after Day LH + 7).

Blood sampling

Blood samples (8–10 ml) were obtained by venepuncture daily between 16:00 and 18:00 h. A haemoglobin test was carried out twice during the cycle. Serum was separated and stored at −20°C. Samples from one cycle were measured in one batch to avoid bias due to interassay variations.

Hormone assay

The radioimmunoassay kits of LH, FSH, prolactin, oestradiol and progesterone were generously provided by WHO. The radioimmunoassay method was established according to the WHO manual (WHO, 1980) and the relevant data are as follows.

LH. The antiserum was provided by Professor W. Butt (Birmingham, U.K.). The sensitivity was 1 i.u./l and cross-reactions were 0·5% with hFSH-AFP/574C, 0·2% with LHα-NM/14, 50% with LHβ-NM/14, 1·5% with hCG-75/737, 0·6% with hTSH–AFP/1001C, 1·0% with hCGβ-75/551 and 0·4% with hCGα-75/569.

FSH. The antiserum was provided by Professor W. Butt and the sensitivity of the assay was 1 i.u./l. Cross-reactions were 0·1% with hLH-AFP/1560B, 0·1% with hCG-75/537, 0·5% with hTSH-AFP/1001C, 0·1% with hCG-75/569 and 0·1% with hCG-75/551.

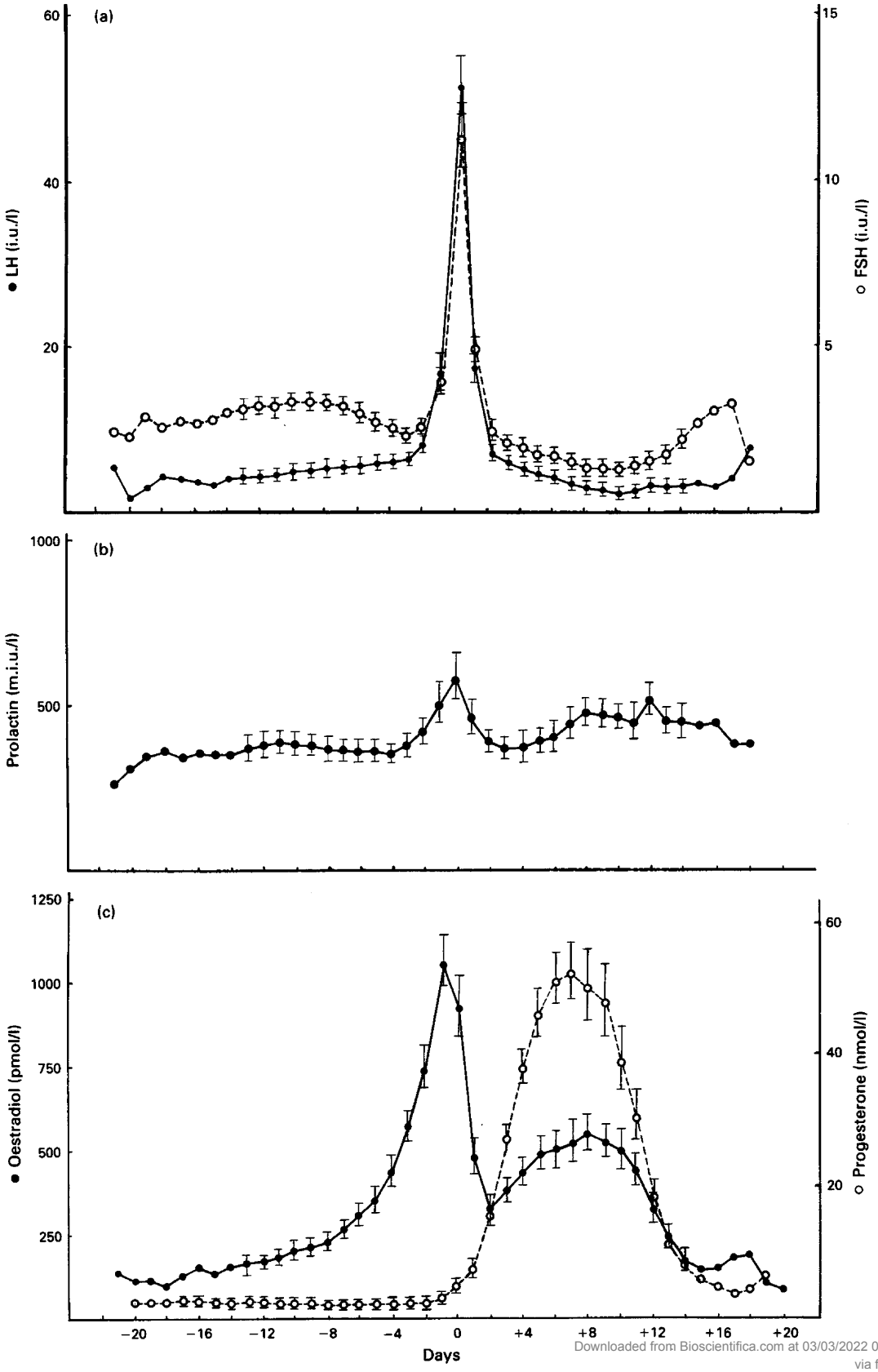
Prolactin. The antiserum was provided by Professor A. F. Parlow (Los Angeles, U.S.A.). The assay sensitivity was 65 m.i.u./l and there was 0·05% cross-reaction with human growth hormone.

Oestradiol. The antiserum was provided by Professor W. Butt. The sensitivity was 7–15 pmol/tube and cross-reactions were 1·7% with oestrone, <0·0002% with testosterone and <0·0001% with cortisol.

Progesterone. The antiserum was provided by EIR (Würenlingen, Switzerland). The sensitivity was 10–40 fmol/tube. Cross-reactions were < 0·01% with cortisol, < 0·2% with testosterone, < 3% at 17α-hydroxyprogesterone, < 7% with 5α-dihydroprogesterone and < 3% with 20α-dihydroprogesterone.

Quality control pools were established as described previously (Liu *et al.*, 1981; Liu & Wang, 1983). The intra- and inter-assay variation coefficients of the internal quality control pools for LH, FSH, prolactin, oestradiol and progesterone were all within 10% and 15% respectively.

Fig. 1. Daily serum concentrations of immunoreactive LH and FSH (a), prolactin (b) and oestradiol and progesterone (c) in 100 normally menstruating Chinese women. Geometric mean values are given with 95% confidence limits (± 1·96 s.e.) shown by the vertical bars. The results are related to the day of the LH peak (Day 0).



Statistical methods

The geometric mean (g.m.), s.d., g.m. ± 1·96 s.e. (95% confidence limit), Student's *t* test and correlation analysis were calculated and programmed by computer. The programme was designed by the Department of Public Hygiene in Shanghai 1st Medical College. The statistical analysis of the complete cycle is presented in the tables.

Results

In Fig. 1, the geometric mean serum values were grouped around the day of the LH peak (designated as Day 0).

LH

The cyclic changes of LH are shown in Fig. 1(a). The geometric means of LH at different stages of the cycle are presented in Table 1. The geometric mean of the LH peak (Day 0) was 51·64 i.u./l. The geometric mean of the values in the follicular phase (6·74 i.u./l) was significantly higher than that in the luteal phase (4·72 i.u./l) ($P < 0·001$). It can be seen from the data given in Table 3 that the average LH concentration of the first 6 days of the cycle was < 10·6 i.u./l and the LH peak value exceeded 28·48 i.u./l. On the other hand, the mean concentration for Days − 7 to − 3 differed from those of Days + 3 to + 7 ($P < 0·001$; see Table 1). As shown in Table 5, the length of the entire cycle and that of the follicular phase were significantly correlated with the mean LH value of Days −7 to −3 ($P < 0·001$). In addition, the length of the entire cycle was correlated with the value of the midcycle LH peak concentration ($P < 0·001$).

FSH

The pattern of the cyclic change of FSH is also shown in Fig. 1(a). The day of FSH peak was the same as that of the LH peak. The geometric mean of the FSH peak was 11·52 i.u./l (Table 1). The geometric mean of the follicular phase (3·32 i.u./l) was significantly higher than that in the luteal phase (1·91 i.u./l) ($P < 0·001$) (Table 1). The mean FSH value of Days LH − 7 to LH − 3 (2·77 i.u./l) was significantly higher than that of Days LH +3 to LH +7 (1·83 i.u./l) ($P < 0·001$). No correlation was found between any set of FSH concentrations, and the length of the cycle or its different phases (Table 5).

Prolactin

The cyclic change of prolactin was irregular as shown in Fig. 1(b). The geometric mean of prolactin at midcycle (579·08 m.i.u./l) was significantly higher than that in the follicular (389·14 m.i.u./l) and luteal (435·82 m.i.u./l) phase (Table 1). There was no correlation between any set of prolactin concentrations and the length of the cycle or its different phases (Table 5).

Oestradiol

The cyclic change of the mean oestradiol profile is shown in Fig. 1(c). It can be seen from Table 2 that the geometric mean of the first preovulatory oestradiol peak was 1229 pmol/l, and the mean oestradiol level of the second maximum in the luteal phase was 841·78 pmol/l. The former was significantly higher than the latter ($P < 0·001$) (Table 2). During Days 1 to 6 of the cycle, the average oestradiol concentration was between 94 and 433 pmol/l, and the preovulatory peak was between 704 and 2222 pmol/l (Table 3). In addition, the length of the cycle was negatively

Table 1. LH, FSH and prolactin concentrations at different stages of the menstrual cycle in 100 Chinese women

	Follicular phase	Early follicular phase	Late follicular phase		Midcycle LH surge		Early luteal phase	Late luteal phase	Luteal phase
Days	LH−22→0	LH−22→−8	LH−7→−3	LH−1	LH 0	LH+1	LH+3→7	LH+8→20	LH+1→20
LH (i.u./l)									
n	1479	679	500	100	100	100	500	740	1440
g.m.	6·74[a]	4·61[b]	5·89[bc]	17·21	51·64	17·60	5·06[c]	3·56	4·72[a]
s.d	2·4	1·88	1·8	1·82	1·43	1·86	2·01	2·22	2·34
FSH (i.u./l)									
n	1479	679	500	100	100	100	500	740	1440
g.m.	3·32[a]	3·17[b]	2·77[bc]	4·06	11·52	4·98	1·83[c]	1·66	1·91[a]
s.d.	1·74	1·52	1·54	1·66	1·43	1·68	1·72	1·89	1·93
Prolactin (i.u./l)									
n	1479	679	500	100	100	100	500	740	1440
g.m.	389·14[a]	368·85	360·54[b]	507·62	579·08	463·20	398·5[c]	466·62[bc]	435·82[a]
s.d.	1·64	1·61	1·61	1·64	1·62	1·67	1·66	1·66	1·68

Values are geometric mean (g.m.) and standard deviation (s.d.) for the no. of blood samples indicated (*n*).
For each hormone, values with similar superscript letters are significantly different, $P < 0{\cdot}001$ (Student's *t* test).

Table 2. Oestradiol and progesterone concentrations in different phases of the menstrual cycle in 100 Chinese women

	Follicular phase	Early follicular phase	Late follicular phase	Peak	Nadir	Early luteal phase	Late luteal phase	Luteal maximum	Luteal phase
Days	LH−22→0	LH−22→−8	LH−7→−3	LH−1,0	LH+2,+3	LH+3→7	LH+8→20		LH+1→20
Oestradiol-17β (pmol/l)									
n	1480	680	500	100	100	500	752	100	1452
g.m.	323·96[a]	182·24[b]	379·48[bc]	1229·12	241·67	476·14[c]	350·20	841·78	397·0[a]
Progesterone (nmol/l)									
n	1481	681	500	100		500	751	100	1451
g.m.	1·72[a]	1·59	1·49	4·19[a] (initial rise)		40·91	19·32	53·27	22·8

Values are geometric means (g.m.) for the no. of samples indicated (*n*).
For each hormone values with similar superscript letters are significantly different, $P < 0{\cdot}001$ (Student's *t* test).

correlated with the mean oestradiol concentration of the follicular phase ($P<0.05$) and the mean oestradiol value at Days 1–6 ($P<0.01$) (Table 5). The length of the follicular phase was also negatively correlated to the mean oestradiol concentration at Days 1–6 ($P<0.001$) (Table 5).

Progesterone

The cyclic change of mean progesterone profile is shown in Fig. 3(c). It can be seen from Tables 2 and 3, that the mean maximum progesterone value in the luteal phase (5 days) was 53·27 nmol/l, and the mean value at Days 1–6 was between 0·83 and 3·57 nmol/l. Table 5 shows that there was no correlation between any set of progesterone concentrations and the length of the cycle or its different phases.

The days of the cycle on which the preovulatory oestradiol and LH peaks occurred as well as the days of highest FSH levels are indicated in Table 4. It can be seen from the data that more than

Table 3. Certain characteristics of immunoreactive LH, FSH, prolactin, oestradiol and progesterone concentrations during the menstrual cycle in 100 normally menstruating women

Hormones	Characteristic	Limits
LH (i.u./l)	Mean level of Days 1–6	1·81–10·6
	Mean level of Days LH −7 to LH −3	2·28–15·78
	Preovulatory (midcycle) peak	28·48–93·65
	Mean luteal-phases level	1·17–18·98
	Mean throughout the cycle	1·33–23·92
FSH (i.u./l)	Mean level of Days 1–6	1·77–5·62
	Mean level of Days LH −7 to LH −3	1·36–5·66
	Preovulatory (midcycle) peak	6·39–20·74
	Mean luteal-phase level	0·65–5·59
	Mean throughout the cycle	0·85–7·52
Prolactin (mi.u./l)	Mean level of Days 1–6	203·8–755·4
	Mean level of Days LH −7 to LH −3	165·4–785·5
	Preovulatory (midcycle) peak	385·7–1394·7
	Mean luteal-phase level	187·0–1015·6
	Mean throughout the cycle	178·7–947·1
Oestradiol (pmol/l)	Mean level of Days 1–6	94–433
	Preovulatory	704–2222
	Luteal maximum	449–1580
	Mean luteal-phase level	128–1232
Progesterone (nmol/l)	Mean level of Days 1–6	0·83–3·57
	Luteal maximum	38·33–108·62
	Mean luteal-phase level	9·6867–120·80
	Mean throughout the cycle	4·32–29·13

Table 4. Percentage of cycles exhibiting peak serum concentrations of oestradiol, LH and FSH on different cycle days in 100 normally menstruating women

Cycle days	1–7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	>22
Oestradiol (%)	1	1	2	5	8	11	15	14	14	6	6	1	6	3	1	3	3
LH (%)			1	4	6	9	13	19	13	14	2	7	5	2	3	2	0
FSH (%)			1	2	6	10	13	19	14	13	3	7	5	2	3	2	0

Table 5. Correlation coefficients (r) between the length of cycle and its various phases (days) and different hormonal indices in 100 normally menstruating women

Length of	Characteristic	LH	FSH	Prolactin	Oestradiol	Progesterone
Entire cycle	Mean level throughout the cycle	0·21*	−0·06	−0·05	−0·076	0·096
Entire cycle	Mean level follicular phase	0·17	−0·09	−0·06	−0·249*	−0·033
Entire cycle	Mean level luteal phase	0·11	−0·18	−0·02	0·089	0·100
Entire cycle	Mean level Days 1–6	−0·01	−0·07	−0·06	−0·287**	0·054
Entire cycle	Mean level Days LH −7 to LH −3	0·42***	−0·02	−0·01	−0·076	0·039
Entire cycle	Peak level	0·36***	0·10	0·05	−0·031	0·010
Follicular phase	Mean level Days 1–6	−0·08	−0·10	−0·10	0·331***	0·006
Follicular phase	Mean level Days LH −7 to LH −3	0·45***	0·03	−0·06	−0·059	0·106
Follicular phase	Peak level	0·17	0·12	0·05	−0·013	−0·055
Luteal phase	Mean level luteal phase	0·08	0·08	0·05	−0·020	0·036
Luteal phase	Mean level Days LH −7 to LH −3	−0·19	−0·07	0·09	−0·002	−0·117
Luteal phase	Peak level	0·16	−0·07	−0·02	−0·017	−0·099

*$P<0·05$; **$P<0·01$; ***$P<0·001$.

67% of the preovulatory oestradiol and LH peaks occurred between the 12th and 18th days of the cycle, and more than 89% of the preovulatory oestradiol and LH peak occurred between the 10th and 20th days of the cycle.

The luteal phase lasted for 10 days in 2 women, 11 in 5, 12 in 9, 13 in 11, 14 in 21, 15 in 24, 16 in 18, 17 in 8 and 18 in 2. Therefore 65% of the women exhibited a luteal phase between 12 and 15 days, and 91% of the 100 subjects exhibited a luteal phase between 12 and 17 days.

Discussion

In the present study, 100 Chinese women in Shanghai were investigated to establish the normal hormone pattern during the menstrual cycle by daily measurement of hormone in serum. The present results are similar to those previously reported for the hormonal changes in Swedish, Thai, African, and Singaporian women (Johansson, Wide & Gemzell, 1971; Briggs & Briggs, 1972; L'Hermite, Delvoye, Nokin, Vekemans & Robyn, 1972; McNeilly & Chard, 1974; Saxena, Dusitsin, Pashyachinad & Smith, 1974; Epstein, McNeilly, Murray & Hockaday, 1975; Lehman, Just-Nastansky, Czygan & Bettendorf, 1976; Salmon, Chew & Ratnam, 1976; Speroff, Glass & Kase, 1978; Werawatgoompa *et al.*, 1981). Different methods and different reference standards were used in the measurement of hormones by various laboratories, and so the absolute values of each hormone are difficult to compare amongst ethnic groups. However, the samples of 100 Chinese and 68 Swedish women are large enough to compare. The LH and FSH peak values in Chinese women (51·64 and 11·52 i.u./l) (Table 1) were significantly higher than those in Swedish women (21 and 6 i.u./l) (Fig. 1 and Fig. 2 in Landgren *et al.*, 1980).

In most of the references published so far, there were no differences between normal Caucasian and Asian women in the concentrations of 5 hormones (LH, FSH, prolactin, oestradiol and progesterone) during the menstrual cycle. The data in the present paper confirmed this conclusion.

Vanderkerckhove & Dhont (1972) have suggested that there is a relationship between the length of the luteal phase and the mean luteal concentration of LH, but this was not confirmed in the present study (Table 5) or in that of Landgren *et al.* (1980).

We found a correlation between the length of the follicular phase and the mean LH value at Days LH −7 to LH −3, and a negative correlation with the mean oestradiol value at Days 1–6 of the cycle. There was a positive correlation between the length of the cycle and the mean LH concentrations throughout the cycle or at Days LH −7 to LH −3, or at the midcycle peak of LH value,

Table 6. Percentage of cycles with certain concentrations of serum progesterone (nmol/l) for different lengths of time in 100 normally menstruating women

No. of days with elevated value	Progesterone conc. exceeding:				
	17 nmol/l	23 nmol/l	32 nmol/l	38 nmol/l	53 nmol/l
6	97	94	81	64	27
5	98	96	90	73	33
4	98	97	90	80	33
3	100	99	95	88	59
2	100	99	97	92	71

and a negative correlation between cycle length and the mean oestradiol values at 1–6 days of the cycle, or during the entire follicular phase (Table 5). Hence the combination of high initial oestradiol concentrations with low initial LH values was associated with relatively short cycles and *vice versa*. Most of these correlations regarding LH confirmed those of Landgren *et al.* (1980).

The data presented in Table 6 revealed that 98 of 100 normally menstruating women in Shanghai exhibited serum progesterone concentrations higher than 17 nmol/l for a minimum of 5 days and 96 of these 100 women had values above 23 nmol/l during the same period. It is suggested that these concentrations are more suitable than previously recommended figures for distinguishing between normal and insufficient luteal function (Diczfalusy & Landgren, 1977). The basic information obtained on the menstrual cycle in this study is important and indispensable to family planning research for Chinese women.

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References

Bing Sheng-min, Yan Ben-yuan, Lu Xiang-yun, Yuan Yao-e, Lin Ying-fen, Chen Xian-jiao, Zhu Xiu-ying & Qiao Feng-yun (1982) The serum FSH, LH, prolactin, oestradiol and progesterone level in the normal postmenopausal women. *Shanghai Medicine* **5,** 219–221.

Briggs, M.H. & Briggs, M. (1972) Steroid hormone concentrations in blood plasma from residents of Zambia, belonging to different ethnical groups. *Acta endocr., Copenh.* **70,** 619–624.

Diczfalusy, E. & Landgren, B.M. (1977) Hormonal changes in the menstrual cycle. In *Regulation of Human Fertility,* pp. 21–71. Ed. E. Diczfalusy. Scriptor, Copenhagen.

Epstein, M.F., McNeilly, A.S., Murray, M.A.F. & Hockaday, T.D.R. (1975) Plasma testosterone and prolactin in the menstrual cycle. *Clin. Endocr.* **4,** 531–535.

Johansson, E.D.B., Wide, L. & Gemzell, C. (1971) Luteinizing hormone (LH) and progesterone in plasma and LH and estrogens in urine during 42 normal menstrual cycles. *Acta endocr., Copenh.* **68,** 512–521.

Landgren, B.M., Unden, A.L. & Diczfalusy, E. (1980) Hormonal profile of the cycle in 68 normally menstruating women. *Acta endocr., Copenh.* **94,** 89–98.

Lehmann, F., Just-Nastansky, I., Czygan, P.J. & Bettendorf, G. (1976) Effects of 17α-ethinyl-19-nortestosterone on corpus luteum function. *Eur. J. Obstet. Gynaec. Reprod. Biol* **6,** 219–222.

L'Hermite, M., Delvoye, P., Nokin, J., Vekemans, M. & Robyn, C. (1972) In *Prolactin and Carcinogenesis,* pp. 81–97. Eds A. R. Boyns & K. Griffiths. Alpha Omega Alpha Publishing, Cardiff.

Liu Shi-fan & Wang Zhong-xing (1983) The establishment and application of quality control pool in radioimmunoassay. *Chin. J. Nuclear Med. (Beijing)* **3,** 116–117.

Liu Shi-fan, Wang Zhong-xing, Gu Xi-gen, Shen Wei-xiong, Sheng Su-hung & Yan A-lin (1981) The radioimmunoassay of seven hormones during menstrual

cycles in 19 cases. *Reprod. Contraception (Shanghai)* **1,** 43–47.

McNeilly, A.S. & Chard, T. (1974) Circulating levels of prolactin during the menstrual cycle. *Clin. Endocr.* **3,** 105–112.

Salmon, J.A., Chew, P.C.T. & Ratnam, S.S. (1976) Plasma hormone concentrations during the menstrual cycle of normal Chinese women. *Acta obstet. gynaec. scand.* **55,** 239–243.

Saxena, B.N., Dusitsin, N., Pashyachinad, V. & Smith, I. (1974) Luteinizing hormone, oestradiol and progesterone levels in the serum of menstruating Thai women. *J. obstet. Gynaec. Br. Commonw.* **81,** 113–119.

Speroff, L., Glass, R.H. & Kase, N.G. (Eds) (1983) In *Clinical Gynecologic Endocrinology and Infertility*, 3rd edn, pp. 75–100. Williams & Wilkins, Baltimore.

Vanderkerckhove, D. & Dhont, M. (1972) The relationship between serum LH levels, as determined by radioimmunoassay and the life span of the corpus luteum. *Annls Endocr.* **33,** 205–210.

Werawatgoompa, S., Tankeyoon, M., Kongseripong, R., Chaniyon, K., Virutamasen, P., Dusitsin, N. & Boonsiri, B. (1981) Hormonal changes in normal menstrual cycle of Thai women. *Contraception* **23,** 301–313.

WHO (1980) Programme for the provision of assay reagents for the radioimmunoassay of matched hormones in reproductive physiology: Method Manual, 4th edn. Geneva.

Wu Yi-e, Peng Xin-ying, Jin Yu-cui, Wang Yi-fu, Luo Bang-rao, He Qi-jiu & Zhou Li-li (1982) Evaluation of serum FSH, LH, prolactin, oestradiol and progesterone in diagnosis of secondary amenorrhea. *Shanghai Medicine* **5,** 586–590.

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