Relationships between the luteinizing hormone surge and other characteristics of the menstrual cycle in normally ovulating women

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Objective: To describe the LH surge variants in ovulating women and analyze their relationship with the day of ovulation and other hormone levels.
Design: Secondary analysis of a prospective cohort observational study.
Setting: Eight natural family planning clinics.
Subjects: Normally fertile women (n = 107) over 283 cycles.
Intervention(s): Women collected daily first morning urine, charted basal body temperature and cervical mucus discharge, and underwent serial ovarian ultrasound.
Main Outcome Measure(s): Urinary LH, FSH, estrone-3-glucuronide (E3G), pregnanediol-3α-glucuronide (PDG), and day of ovulation by ultrasound (US-DO).
Result(s): Individual LH surges were extremely variable in configuration, amplitude, and duration. The study also showed that LH surges marked by several peaks were associated with statistically significant smaller follicle sizes before rupture and lower LH level on the day of ovulation. LH surges lasting >3 days after ovulation were associated with a lower E3G before ovulation, a smaller corpus luteum 2 days after ovulation, and a lower PDG value during the first 4 days after ovulation.
Conclusion(s): In clinical practice, LH profiles should be compared with the range of profiles observed in normally fertile cycles, not with the mean profile. (Fertil Steril® 2013;99:279–85. ©2013 by American Society for Reproductive Medicine.)
Key Words: LH surge, ovulation, menstrual cycle, luteinizing hormone

In clinical practice, as in research on menstrual cycles, the gonadotropin and ovarian hormone secretion profiles considered to be normal are averages of individual hormonal profiles, with a "normal range." This range of normal variability is used in everyday practice to diagnose cycle abnormalities. However, the variability of menstrual cycles, both between and within women, is a well known phenomenon (1–3). In the past, studying cycles that they supposed to be normal, many researchers discarded a significant number of these cycles before calculating the normal variability. For example, Renaud et al. (4), Queenan et al. (5), and Polan et al. (6) classified as abnormal 44%, 22%, and 36% of spontaneous cycles, respectively. These proportions are too high to be accepted without further consideration.

In the past decade, several authors have proposed to go beyond a simple description of a range of normal values and classify hormone trajectories. Alliende (7) showed that most individual hormone trajectories in women of proven fertility differed considerably from the mean hormone curves. That author recommended giving more attention to this diversity in future research.

Park et al. (8) emphasized the extreme variability of the LH surge and showed that ovulatory LH surges

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are not of a single type but are rather extremely variable in configuration, amplitude, and duration. The LH surge configuration is classically described as a single peak, but it may also be a double-peak or a plateau (7, 8). Park et al. described a large range of LH amplitudes: 2.5–14.8 times the baseline level. The duration of the LH surge, classically 3 days, was found to range from 5 to 11 days. However, those authors did not study the relationships between LH surge variants (8) (configuration, amplitude, and duration) and the profiles of other hormones, nor did they identify the timing of the LH surge relative to the day of ovulation.

In the middle 1990s, a database collected daily urinary hormone measures, recordings of basal body temperature, cervical mucus observations, and serial ovarian ultrasound in normally ovulating women. A previous analysis (9) has examined the mean hormone levels and their correlation with ovulation but did not analyze the variants of ovarian and gonadotropin secretions. The present article is a secondary analysis addressing the question of the relationships between the LH surge variants, the profiles of other hormones, and the process of ovulation and luteinization.

MATERIALS AND METHODS

Subjects

The subjects of this prospective cohort study were approached in the middle 1990s in eight natural family planning centers across five European countries: Aix-en-Provence, Dijon, and Lyon, France; Milano and Verona, Italy; Düsseldorf, Germany; Liège, Belgium; and Madrid, Spain.

The inclusion criteria were ostensibly healthy menstruating women aged 18–45 years, with a history of previous menstrual cycle lengths of 24–34 days and an experience in natural family planning methods, i.e., recording of basal body temperature and observation of cervical mucus. Women with frequent anovulatory cycles, taking any hormonal treatment, with known disturbances of follicular development, or with a history of infertility were excluded. Women with a history of gynecologic surgery, such as hysterectomy, tubal ligation(s), or pelvic inflammatory disease, as well as runners, breastfeeding women, and those $\leq$3 months postpartum were also excluded. Each of the 107 women meeting all of the inclusion criteria contributed with an average of 3 cycles. The study examined 326 cycles.

At study initiation, each woman completed a standard questionnaire and underwent a physical examination. The data collected were current age, age at menarche, current body mass index (BMI), gynecologic history, parity, past oral contraceptive use, lifestyle habits, such as smoking, special diets, and physical activity (hours per week), and current stress (general subjective feeling).

The initial study for which the data were collected was a multicentered collaborative study coordinated by Claude Bernard University (Lyon, France) (9). The study obtained Institutional Review Board approval from the Comité Consultatif de Protection des Personnes dans la Recherche Biomédicale de Lyon. The women were informed of the purpose of the investigation and told that they were free to withdraw at any time, and each of the participants gave her written informed consent. The study procedures were carried out in accordance with the Ethical Standards for Human Experimentation established by the Declaration of Helsinki.

Investigations

During the studied cycles, each woman recorded daily, in a specific individual chart, her basal body temperature (BBT) before bed rise, as well as the date, the day of the cycle, and any event or condition that might affect BBT (late rise, stress, illness, insomnia, etc.) (10, 11).

Two or three times daily, each woman checked the opening of the vagina for changes in cervical mucus and recorded in her chart the sensation (dry, moist, wet, or lubricative) and the consistency (tacky, creamy, or stretchy) (12–14).

The women collected daily first morning urine samples, which were immediately divided into aliquots of 10–12 mL and frozen at -20°C in tubes containing gentamicin sulphate. They were later unthawed and assayed in the same laboratory in a single session for quantitative hormone detection of estrone-3-glucuronide (E3G), pregnanediol-3α-glucuronide (PDG), FSH, and LH with the use of time-resolved fluorometric immunosorbent assays (Delfia). All samples from each woman were tested in duplicate in the same assay and the results adjusted for creatinine (Cr). Interassay variations were negligible; intra-assay variations were 5.7%, 6.8%, 7.9%, and 8.0% for PDG, E3G, LH, and FSH, respectively (9).

Serial transvaginal ovarian ultrasounds with follicle measurement were performed by a single physician per center. Scanning was performed every other day until a follicle reached 16 mm and then daily until evidence of ovulation.

The maximum follicle size was the maximum diameter of the largest follicle observed by ultrasonography during the cycle. The ultrasound-determined day of ovulation (US-DO) was defined as the 24-hour interval between the visualization of a mature follicle in one scan and evidence that ovulation had occurred in the subsequent scan.

Further details concerning investigations were previously published (9).

LH Surge Variants

The LH surge was the series of high LH values close to the US-DO.

Amplitude. In agreement with Park et al. (8), we computed the baseline LH as the mean of five daily LH values immediately before the onset of the LH surge. The LH peak was the maximum LH value during the surge. The amplitude of the LH surge was the difference between the peak and the baseline LH values. The LH surge fold increase was the peak LH value divided by the baseline LH value.

Duration. To define the onset and the end of the LH surge, we drew a horizontal line at 30% of the amplitude of the LH peak. The onset and the end of the surge were respectively the first and last days when the LH surge was above the 30% line. The duration of the LH surge was the number of days above that line.

Configuration. The LH surge was classified as single spiked if the LH peak was maintained over the horizontal line at 30% of the amplitude of the LH peak for $\leq$5 days. It was classified as a plateau if the LH level was maintained over the 30% line for >5 days. If the LH surge was marked by troughs, i.e., days with a LH level below the 30% line, the LH surge was classified as biphasic (two peaks) or multiple peaks.

Position relative to ovulation. The LH surge was classified as prolonged if LH was still higher than the horizontal line at 30% of the amplitude of the LH peak >3 days after the US-DO.

Other Characteristics of the Menstrual Cycle

Phases of the cycle. The cycle was divided into three phases: the latency phase (from the first day of the cycle to the last day before mucus was observed), the periovulatory phase (from the first day of mucus observed at the vulva [15] to US-DO), and the luteal phase (from the day after US-DO to the end of the last day before menses). Cycles with a luteal phase of >17 days were considered to be possible pregnancies. Proven pregnancies were defined by a positive urine hCG test.

Hormonal levels. The average level of each hormone was calculated on days 2, 3, and 4 of the cycle (early follicular phase), on US-DO ± 1 (periovulatory phase), and on US-DO + 5, + 7, and + 9 (luteal phase).

Statistical Analysis

A descriptive analysis of the cycle characteristics was performed using the mean and 95% confidence interval together with minimum, median, and maximum values for quantitative variables and frequencies for qualitative variables.

The different patterns of LH surges were classified by frequency according to the above definitions (see various typical examples in Fig. 1). A descriptive analysis of the LH surge characteristics was performed using the geometric mean, 95% confidence interval, minimum, median, and maximum values for quantitative variables.

Women and cycle characteristics associated with different patterns of LH surges were compared statistically with the use of Fisher exact test for categoric variables and Student *t* test for continuous variables. For the latter tests, variables whose distributions were not normal underwent a log transformation.

Finally, geometric means and 95% confidence intervals for PDG, E3G, and basal body temperature values were estimated separately for the cycles whose LH profiles lasted less than and more than 3 days after US-DO and presented graphically.

All statistical analyses were performed using the SAS software. A P value of $<.05$ was considered to represent statistical significance (two sided).

RESULTS

Women and Cycle Characteristics

The 107 women studied were 19–44 years old (median 32.6) and 50% were 29–39 years old. Sixty-nine (67.6%) of them had at least one child before the study. The BMIs ranged from 17.1 to 28.3 kg/m^2. Eleven women (10.8%) reported current smoking and 30 (29%) regular physical activity.

In 28 cycles out of the 326 monitored, the first ultrasound was performed after ovulation, and in 15 others it was not possible to affirm ovulation by ultrasound, leaving 283 ovulatory cycles for the analysis. A flow diagram showing inclusion and exclusion characteristics of woman and cycles is provided in Supplemental Figure 1 (available online at www.fertstert.org).

The characteristics of these 283 ovulatory cycles are presented in Table 1. The mean cycle length was 28.1 days (range 22–44 days). The mean time to ovulation was 14.8 days (range 9–33 days), the mean length of the periovulatory phase was 6.3 days (range 1–14 days), and the mean postovulatory phase length was 13.3 days (range 7–17 days).

Two cycles with very peculiar LH profiles (a very high LH surge during the postovulatory phase) were excluded from the study of LH surges, leaving us with 281 cycles.

Examples of LH Surge Variants

Figures 1 and 2 provide typical examples of LH profiles, which illustrate the duration, configuration, and position of the LH surge relative to US-DO.

Figure 1 provides typical examples of LH profiles that illustrate the duration and the configuration of the LH. Figure 1A–1D show that the duration of the LH surge increased with delay of the PDG rise.

Figure 1E shows a single peak: The LH surge is short with a rapid increase and a slow decrease. In Figure 1F, after a first peak, the LH surge plateaus, and Figure 1G and H show, respectively, double and multiple peaks with ≥ 1 day between peaks.

Figure 2A–2C show cycles where the ovulation took place at the onset of the LH surge, the same day as the LH peak, and 2 days later, respectively. In Figure 2D, the LH surge is a multiple-peak surge, the last peak occurring 2 days after ovulation.

Quantitative Description of the LH Surge Variants

Among the 281 cycles, the proportions of single-peaked, plateauing, double-peaked, and multiple-peaked LH surges were 134 (48%), 30 (11%), 93 (33%), and 24 (8%), respectively.

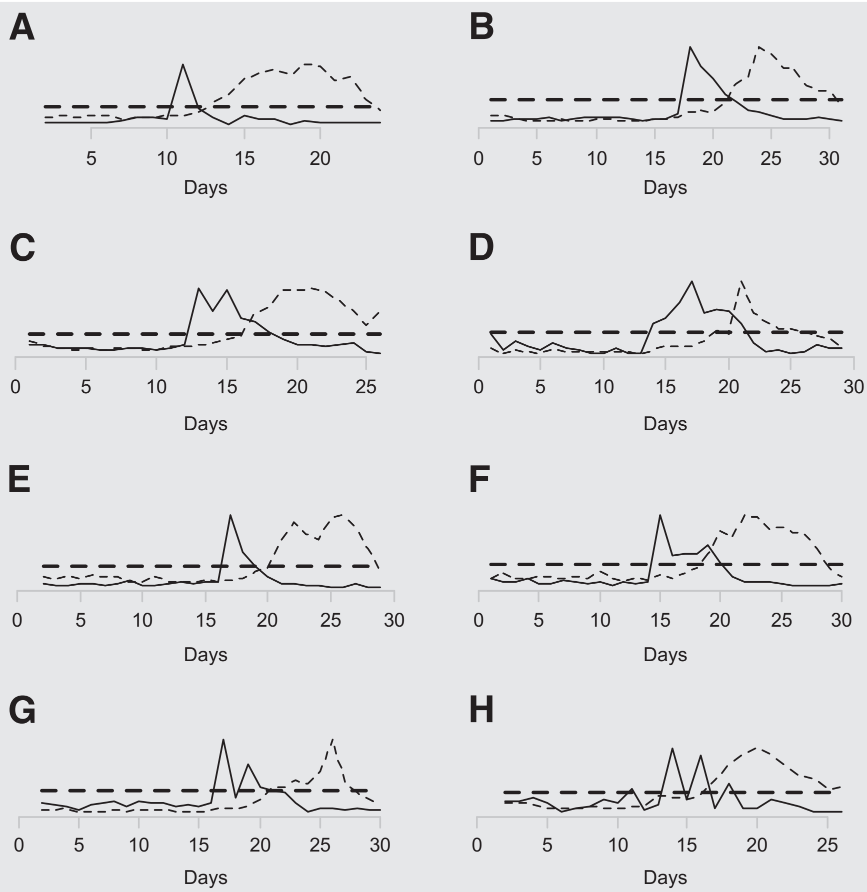
Table 1 provides a description of LH surge characteristics. In average, the LH peak occurred on day 16, i.e., 1.2 days after US-DO. In 210 cycles (75%), the delay between the two events was <2 days; in the other cycles the delay between the LH peak and US-DO was much longer (up to 6 days before and 5 days after). The amplitude of the LH increase varied largely; it ranged from 2.1 to 61 times the baseline level. The mean LH surge duration was 4.8 days (range 1–16 days).

In 17 cycles (6%), the LH surge ended before the US-DO but, in the overwhelming majority of the cycles (94%), the LH surge continued after US-DO; in 60% of the cycles, it lasted >3 days after US-DO.

Relationships between LH Surge Variants and Other Cycle Characteristics

Cycles with double or multiple peaks had smallest average maximum follicle sizes (P=.01) and lowest LH maximum values during the LH surge (P=.03). Supplemental Table 1 (available online at www.fertstert.org) presents a comparison of women's characteristics, cycle lengths, hormone levels, and follicle sizes among three groups of cycles with different configurations of LH surges (single peak, plateau, and double or multiple peaks).

FIGURE 1



The LH surge variants. Examples of cycles with (A) short, (B) medium, (C) double, and (D) prolonged LH surges and (E) single peak, (F) plateau, (G) double peak, and (H) multiple LH peaks. The dashed *horizontal line* represents 30% of the maximum amplitude of the LH peak. The LH and pregnanediol-3α-glucuronide profiles are shown with solid and dashed lines, respectively.

Direito. Variability of the LH surge. Fertil Steril 2013.

Relationships between LH Surge Variants and Women's Characteristics

LH surge characteristics remained consistent within subjects (P=.0392), showing a statistically significant repetition of the same pattern of LH profile within the same woman. A subgroup analysis of LH surge variants according to age (18–39 vs. 40–45 years), did not reach statistical significance (P=.1547).

Relationships between Prolonged LH Surges and Other Cycle Characteristics

Prolonged LH surges (60% of cycles; n = 170) were compared with those that lasted <3 days after US-DO (40% of cycles; n = 111) in terms of women's characteristics, cycle lengths, hormone levels, and maximum follicle sizes. Results are presented in Table 2.

Prolonged LH surges were associated with longer cycles (P<.001), longer latency periods (P<.03), and longer postovulatory phases (P<.001). Prolonged LH surges were also associated with lower E3G levels on the third day of the cycle (P=.03), lower PDG levels (P=.02), and lower LH levels (P=.002) on US-DO as well as higher LH (P<.001) and FSH (P<.03) levels during the postovulatory phase. Furthermore, prolonged LH surges were associated with longer durations (P<.001) and smaller LH increases (12.1 vs. 9.9 times the baseline level; P=.002).

Supplemental Figure 2 (available online at www.fertstert.org) illustrates the differences in the average values of PDG, BBT, E3G, and maximum follicle size for prolonged LH surges versus those lasting <3 days. The graphs and their 95% confidence intervals did not overlap, showing statistical significance. More precisely, prolonged LH surges were associated with: 1) lower E3G levels during the 5 days preceding US-DO; 2) lower PDG levels during the 4 days after US-DO; and 3) a smaller corpus luteum 2 days after US-DO. Prolonged LH surges were apparently associated with lower BBTs on US-DO and thereafter, but the difference did not reach statistical significance.

DISCUSSION

In 2002, Alliende (7) underlined the inadequacy of using the mean hormonal profiles as criteria for normality because

TABLE 1

Selected characteristics of cycles (n = 283) and LH surges (n = 281).

Variable	n	Mean (95% CI)	Min.	Median	Max.
Cycle characteristic					
Cycle length (d)[a]	266	28.1 (27.9–28.2)	22	28	44
Menstruation (d)	283	5.3 (5.2–5.3)	2	5	9
Latency period (d)[b]	224	8.5 (8.3–8.6)	4	8	16
Periovulatory phase (d)[b]	224	6.3 (6.14–6.4)	1	6	14
Time to ovulation (d)	283	14.5 (14.3–14.6)	9	14	33
Luteal phase (d)[a]	266	13.3 (13.2–13.4)	7	13	17
Max. follicle size (mm)[c]	281	22.2 (21.9–22.4)	9	22	39
LH surge characteristic(c)					
LH peak day	281	16 (15.8–16.1)	10	16	31
LH peak to menses (d)[a]	266	12.2 (12.0–12.3)	7	12	16
Baseline LH (mIU/mg Cr)	281	3.8 (3.6–3.9)	0.2	3.2	37.5
Day of onset of LH surge	281	14.7 (14.5–14.8)	8	15	25
LH peak (mIU/mg Cr)	281	34.1(32.9–35.2)	4	28.7	119
LH surge fold increase	281	10.8 (10.3–11.2)	2.1	9.3	61
LH surge duration (d)	281	4.8 (4.67–4.93)	1	5	16
US-DO to LH peak delay (d)	281	−1.2 (−1.3 to −1.10)	−6	−1	5

Note: Cr = creatinine; US-DO = ultrasound-determined day of ovulation.
[a] Four proven pregnancies and seven ovulatory cycles in which the postovulatory phase was >17 days (no pregnancy test performed) were excluded from this analysis.
[b] The missing data concern cycles in which women observed mucus along with menstruation, and therefore the onset of the fertile window could not be determined.
[c] Two cycles with very peculiar LH profiles (a very high LH surge during the postovulatory phase) were excluded from the study of LH surges.

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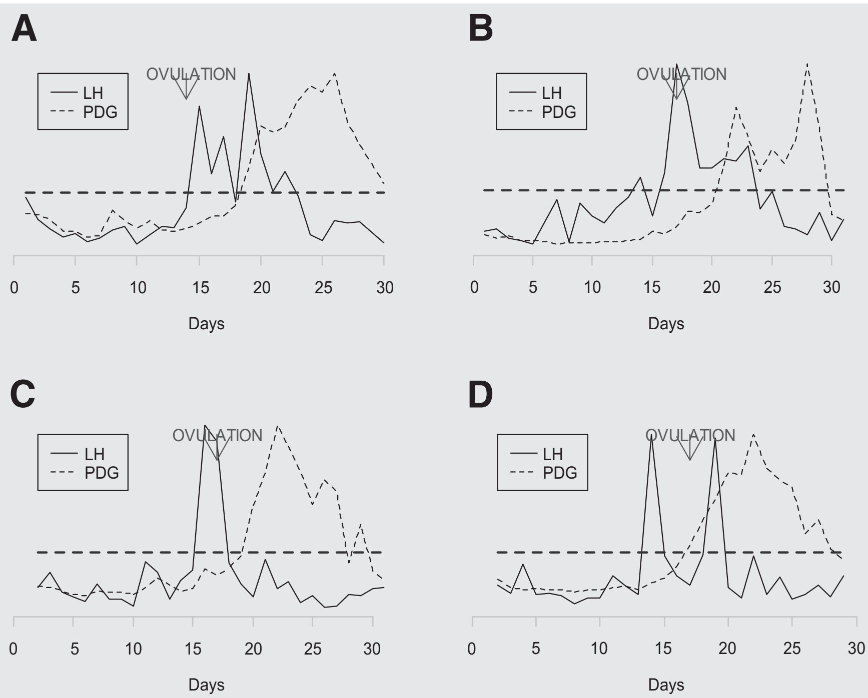
hormonal profiles that differ from the classic mean curves are frequently found in healthy fertile women (56% of 107 women). This was confirmed by the present study: 52% of the individual curves differed in shape from the typical curve. Many other authors have previously reported this fact but without giving specific frequencies (4–6).

In 2007, Park et al. (8) provided a systematic description of LH surges in terms of configuration, amplitude, and duration. In the present study, we followed the criteria they proposed but used up-to-date graphic means. To use a computerized procedure to analyze the surges (in addition to visual identification), we chose to define the onset and

FIGURE 2



Example of cycles during which the ovulation, determined by ultrasound, occurred (A) at the onset of, (B) during, (C) at the end, and (D) after the LH peak. The dashed *horizontal line* represents 30% of the maximum amplitude of the LH peak. The LH and pregnanediol-3α-glucuronide profiles are shown with solid and dashed lines, respectively. The ultrasound-determined day of ovulation is marked by an *arrow*.

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TABLE 2

Prolonged LH surge (> 3 days after ovulation) and other characteristics of the cycle, mean (95% confidence interval).

	Prolonged LH surge		
Characteristics of women and menstrual cycle	**No (n = 111/281)**	**Yes (n = 170/281)**	***P* value**
Woman			
Age (y)	32.2 (31.1–33.4)	32.6 (31.7–33.5)	NS
Menarche (y)	13.1 (12.8–13.4)	13.1 (12.9–13.4)	NS
BMI (kg/m^2)	21.2 (20.8–21.6)	21.3 (20.8–21.6)	NS
Phases of the cycle (d)			
Total	27.8 (27.2–28.3)	28.7 (28.1–29.2)	< .001
Latency	8.1 (7.7–8.5)	8.6 (8.2–9.0)	.03
Periovulatory phase	6.7 (6.1–7.2)	6.0 (5.6–6.4)	NS
Postovulatory phase	12.8 (12.4–13.1)	14.0 (13.6–14.4)	< .001
US-DO	14.9 (14.3–15.4)	14.6 (14.2–15.0)	NS
Hormone levels			
Ovulation day (US-DO)			
E3G (ng/mg Cr)	51.8 (46.6–56.9)	50.5 (45.4–55.6)	NS
PDG (μg/mg Cr)	3.3 (2.9–3.6)	2.8 (2.6–3.0)	.02
LH (mIU/mg Cr)	18.7 (16.3–21.0)	13.5 (12.1–14.9)	.002
FSH (mIU/mg Cr)	5.6 (4.7–6.4)	4.9 (4.3–5.5)	NS
Luteal phase			
E3G (ng/mg Cr)	29.3 (26.4–32.1)	29.8 (26.2–33.3)	NS
PDG (μg/mg Cr)	12.3 (11.3–13.2)	13.0 (12.0–14.0)	NS
LH (mIU/mg Cr)	3.9 (3.1–4.6)	7.5 (6.6–8.5)	< .001
FSH (mIU/mg Cr)	1.5 (1.2–1.7)	1.8 (1.6–2.0)	.03
Follicle max. diameter	22.1 (20.9–23.2)	21.9 (21.3–22.5)	NS
Other characteristics of LH surge			
Duration of LH surge	3.2 (2.9–3.4)	5.81 (5.4–6.2)	< .001
First day of LH surge	14.4 (13.8–14.9)	14.8 (14.4–15.2)	NS
Last day of LH surge	16.6 (16.0–17.1)	19.7 (19.3–20.1)	< .001
LH peak day	15.1 (14.5–15.6)	16.5 (16.1–16.9)	< .001
Fold change of LH	12.1 (10.6–13.5)	9.9 (8.9–10.8)	.002

Note: BMI = body mass index; Cr = creatinine; E3G = estrone-3-glucuronide; NS = not significant (P>.05); PDG = pregnanediol-3α-glucuronide; US-DO = ultrasound-determined day of ovulation.

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the end of the surge by drawing a horizontal line at 30% of the amplitude of the LH peak. This method artificially decreases the estimated duration of the LH surge by at least 2 days. Park et al. estimated the mean duration of the LH surge at 7.6 days, whereas our estimation was 5 days. The use of Park's criteria on a subsample of our dataset confirmed that the difference between the two estimations was most probably due to differences in defining the onset and surge criteria. However, other characteristics of the LH surge are similar; for example, in Park's study, the LH increase varies 2.5- to 14.8-fold vs. 2.2- to 16-fold in ours (the wider range is due to a larger number of cycles). Alliende (7) observed a single short peak in 44% of cycles, a single long plateaued LH surge in 9%, and double peaks in 22%. The corresponding proportions observed by Park et al. (8) were 42%, 14%, and 44%, and herein the proportions were 48%, 11%, and 41%. These results are very close to each other. These three LH surge profiles are compatible with normal ovulation and might be considered to be normal.

The present relationships between the characteristics of the LH surge and other characteristics of the menstrual cycle in normally ovulating women are somewhat innovative. LH surges with multiple peaks (vs. other profiles) were found here to be associated with follicles of smaller sizes just before rupture and with significantly lower LH levels at US-DO. Three different assumptions may explain these observations. First, an abnormal LH peak might be at the origin of a smaller follicle. But FSH, rather than LH, is known to promote the growth of the follicle. Second, upon detection of a small follicle, the hypothalamus might stimulate the release of a second LH peak. But the positive feedback effect of E_2 on LH and FSH peaks around ovulation might be weaker, because of a lower secretion of E_2 by a small versus a large follicle. To our knowledge, this has been already shown in stimulated cycles in mares (17) but not yet in humans. Third, multiple peaks, small follicles, and low LH levels on the day of ovulation could be the consequence of an ignored peculiarity of the cycle.

This study is a secondary analysis of data collected in the middle 1990s, and therefore we were limited by the previously collected data of FSH, LH, PDG, and E3G. Urinary values of these hormones have been proven to correlate well with serum values of FSH, LH, P, and E_2 (18).

Our subjects, though recruited among natural family planning users in eight centers across Europe, are a rather homogeneous cohort. The average BMI was quite low in the population and there were no obese women (BMI range 17.1–28.3 kg/m^2). This may in fact limit the generalization of these data to other populations.

More research is needed to clarify the cause of the LH surge variants. A future study should address the implications of LH surge variability on the probability of conception, which was not possible in this study because of the limited number of pregnancies observed. Several authors have shown differences in the probability of conception associated with differences in

LH surges (16). These results will benefit from confirmatory studies on larger cohorts with daily LH measurements.

The association between prolonged LH surges for more (vs. less) than 3 days after US-DO with lower E3G levels before ovulation, a smaller corpus luteum 2 days after ovulation, and lower PDG levels during the first 4 days after US-DO seems easier to interpret. The analysis of individual cycles tends to confirm that LH is maintained at a high level until *P* exceeds a certain threshold.

CONCLUSION

The present study confirms the diversity of LH surges in cycles of normally fertile women in terms of configuration, amplitude, and duration. This must be taken into account in fundamental physiology research as in clinical practice. Further studies should address the characteristics of hormone profiles in spontaneous conception cycles. This knowledge would probably benefit the treatment of hormonal causes of infertility.

In the present article, two characteristics of the LH surge were associated with the ovulation process: Multiple-peak LH surges were associated with smaller preovulatory follicles; and prolonged LH surges for $>$3 days after ovulation were associated with delayed luteinization. Multiple peaks might be a symptom of follicular insufficiency, and a prolonged LH surge might be a sign of luteal insufficiency. These assumptions can not be tested using our current database but are sufficient to motivate further research.

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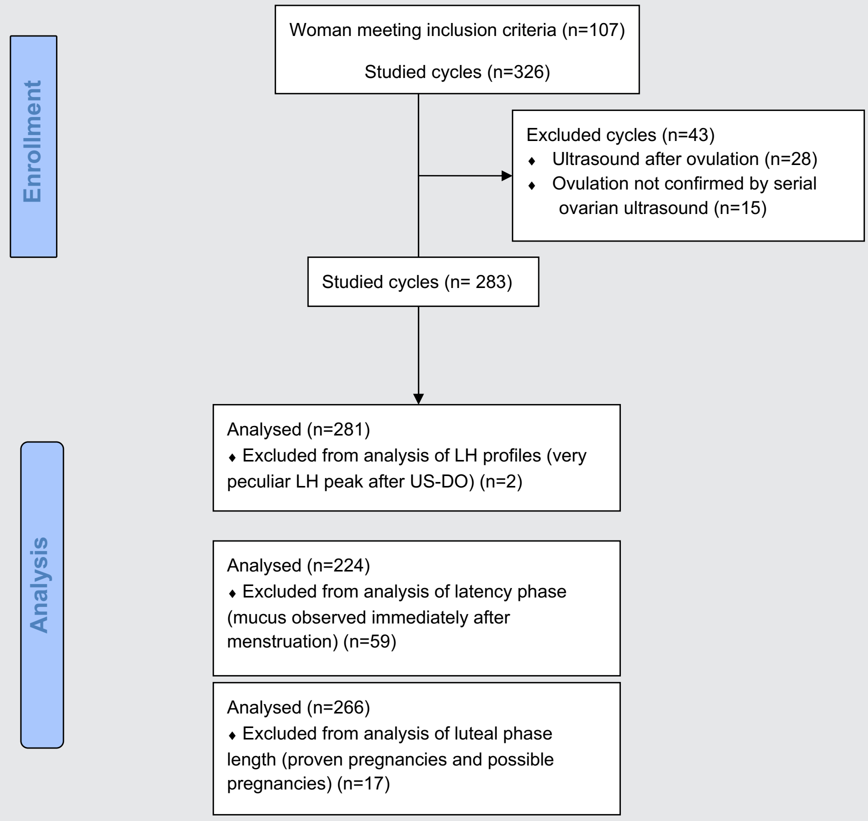
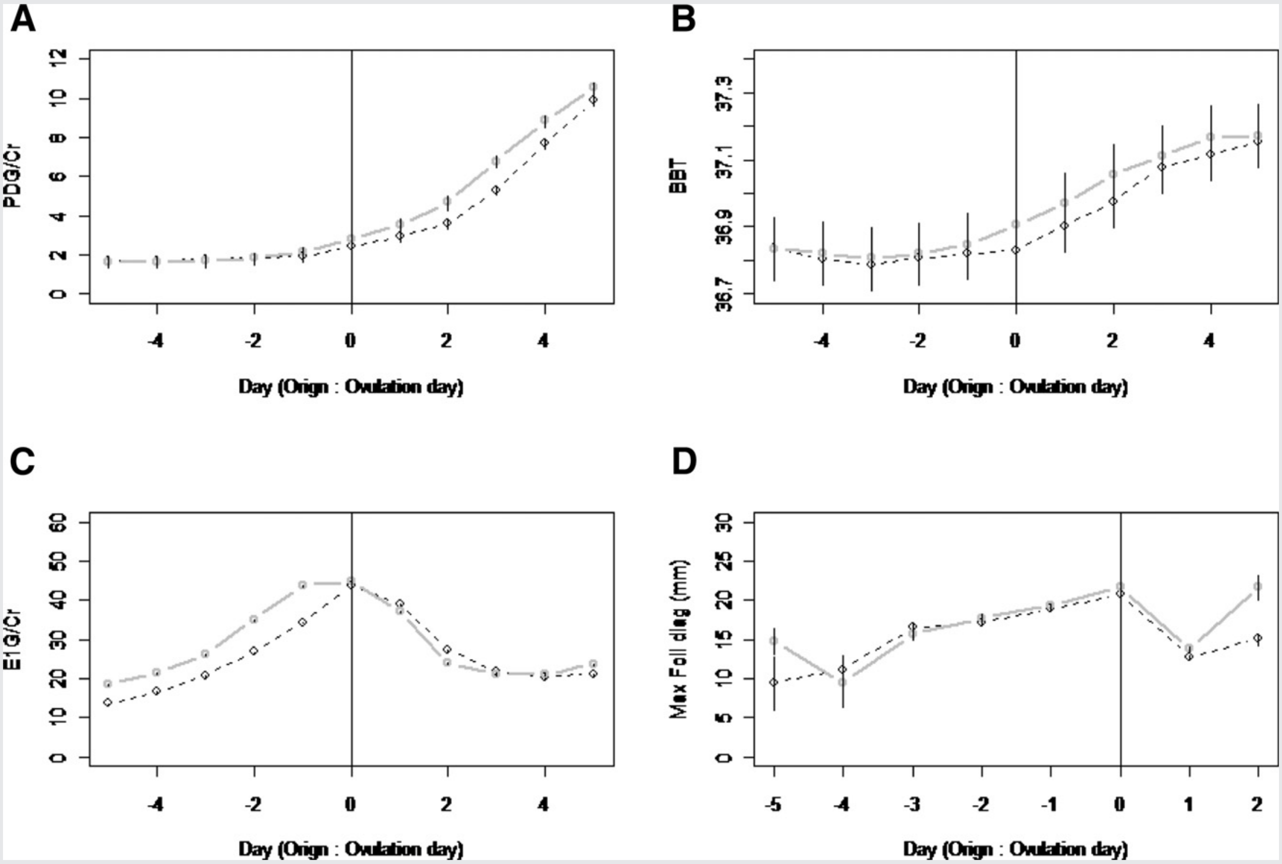
SUPPLEMENTAL FIGURE 1



Flow diagram showing inclusion and exclusion of women and cycles.

Direito. Variability of the LH surge. Fertil Steril 2013.

SUPPLEMENTAL FIGURE 2



(A) Pregnanediol-3α-glucuronide (PDG), (B) basal body temperature (BBT), (C) estrone-3-glucuronide (E3G), and (D) maximum follicle diameter according to the position of the LH surge relative to ovulation. The cycles where the LH profile was prolonged >3 days after the ultrasound-determined day of ovulation (n = 170) are represented by *dashed lines*. The other cycles are represented by *solid lines* (n = 111). 95% confidence intervals are shown.

Direito. Variability of the LH surge. Fertil Steril 2013.

SUPPLEMENTAL TABLE 1

Configuration of the LH surge and other characteristics of the menstrual cycle, mean (95% confidence interval).

Women and menstrual cycle characteristics	Configuration of LH surges			
	Single peak	Plateau	Double or multiple peaks	*P* value[a]
n (n = 281 cycles)	134	30	117	
Women				
Age (y)	31.8 (31.6–31.0)	31.1 (30.7–31.5)	32.3 (32.1–32.5)	NS
Age at menarche (y)	12.9 (12.7–13.0)	13.2 (12.8–13.6)	13.2 (13.0–13.4)	NS
BMI (kg/m^2)	21.2 (21.0–21.4)	20.5 (20.1–20.9)	21.2 (21.0–21.4)	NS
Cycle phases (d)				
Total length	27.8 (27.6–28.0)	28.8 (28.4–29.2)	28.4 (28.2–28.6)	NS
Latency period	8.2 (8.0–8.4)	8.0 (7.4–8.6)	8.2 (8.1–8.5)	NS
Periovulatory phase	5.6 (5.4–5.9)	5.5 (4.9–6.1)	6.2 (5.8–6.6)	NS
Luteal phase	13.2 (13.0–14.4)	14.2 (13.8–14.6)	13.4 (13.3–13.7)	NS
US-DO	14.3 (14.1–14.5)	14.5 (14.1–14.9)	14.7 (14.5–14.9)	NS
Hormone levels				
Ovulation day (US-DO)				
E3G (ng/mg Cr)	46.3 (45.9–46.7)	39.7 (38.9–40.5)	40.0 (39.6–40.3)	NS
PDG (μg/mg Cr)	2.6 (2.4–2.8)	2.5 (1.9–3.1)	2.7 (2.3–3.1)	NS
LH (mIU/mg Cr)	12.9 (12.5–13.3)	12.0 (11.2–12.8)	10.3 (9.9–10.7)	.03
FSH (mIU/mg Cr)	3.4 (2.8–4.0)	4.4 (3.5–5.4)	3.3 (2.7–3.9)	NS
Luteal phase				
E3G (ng/mg Cr)	26.1 (25.7–26.5)	22.5 (21.7–23.2)	24.5 (24.1–24.9)	NS
PDG (μg/mg Cr)	11.4 (11.2–11.6)	10.8 (10.3–11.4)	12.0 (11.6–12.4)	NS
LH (mIU/mg Cr)	3.8 (3.4–4.2)	6.1 (5.3–6.9)	4.3 (4.0–4.7)	NS
FSH (mIU/mg Cr)	0.9 (0.3–1.5)	1.4 (0.2–2.6)	1.2 (0.6–1.8)	NS
Follicle max. diameter	22.3 (22.1–22.5)	22.0 (21.6–22.4)	20.6 (20.4–20.8)	.01
Other characteristics of LH surge				
Duration of LH surge	3.1 (2.9–3.3)	6.5 (6.1–6.9)	5.6 (5.4–5.8)	< .001
First day of LH surge	14.7 (14.5–14.9)	14.5 (14.1–14.9)	14.2 (14.0–14.4)	NS
Last day of LH surge	17.0 (16.8–17.2)	19.9 (19.6–20.4)	19.1 (18.9–19.3)	< .001
LH peak day	15.3 (15.1–15.5)	16.3 (15.9–16.7)	16.0 (15.8–16.2)	.05
LH surge fold increase	10.0 (9.8–10.2)	8.6 (8.0–9.2)	8.9 (8.5–9.3)	NS

Note: BMI = body mass index; Cr = creatinine; E3G = estrone-3-glucuronide; NS = not significant ($P > .05$); PDG = pregnanediol-3α-glucuronide; US-DO = ultrasound-determined day of ovulation.
[a] Student *t* test.

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