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ORIGINAL ARTICLE

Characteristics of menstrual cycles with or without intercourse in women with no known subfertility

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STUDY QUESTION: Does sexual intercourse enhance the cycle fecundability in women without known subfertility?

SUMMARY ANSWER: Sexual intercourse (regardless of timing during the cycle) was associated with cycle characteristics suggesting higher fecundability, including longer luteal phase, less premenstrual spotting and more than 2 days of cervical fluid with estrogen-stimulated qualities.

WHAT IS KNOWN ALREADY: Human females are spontaneous ovulators, experiencing an LH surge and ovulation cyclically, independent of copulation. Natural conception requires intercourse to occur during the fertile window of a woman's menstrual cycle, i.e. the 6-day interval ending on the day of ovulation. However, most women with normal fecundity do not ovulate on Day 14, thus the timing of the hypothetical fertile window varies within and between women. This variability is influenced by age and parity and other known or unknown elements. While the impact of sexual intercourse around the time of implantation on the probability of achieving a pregnancy has been discussed by some researchers, there are limited data regarding how sexual intercourse may influence ovulation occurrence and menstrual cycle characteristics in humans.

STUDY DESIGN, SIZE, DURATION: This study is a pooled analysis of three cohorts of women, enrolled at Creighton Model FertilityCare centers in the USA and Canada: 'Creighton Model MultiCenter Fecundability Study' (CMFS: retrospective cohort, 1990–1996), 'Time to Pregnancy in Normal Fertility' (TTP: randomized trial, 2003–2006) and 'Creighton Model Effectiveness, Intentions, and Behaviors Assessment' (CEIBA: prospective cohort, 2009–2013). We evaluated cycle phase lengths, bleeding and cervical mucus patterns and estimated the fertile window in 2564 cycles of 530 women, followed for up to 1 year.

PARTICIPANTS/MATERIALS, SETTING, METHODS: Participants were US or Canadian women aged 18–40 and not pregnant, who were heterosexually active, without known subfertility and not taking exogenous hormones. Most of the women were intending to avoid pregnancy at the start of follow-up. Women recorded daily vaginal bleeding, mucus discharge and sexual intercourse using a standardized protocol and recording system for up to 1 year, yielding 2564 cycles available for analysis. The peak day of mucus discharge (generally the last day of cervical fluid with estrogen-stimulated qualities of being clear, stretchy or slippery) was used to identify the estimated day of ovulation, which we considered the last day of the follicular phase in ovulatory cycles. We used linear mixed models to assess continuous cycle parameters including cycle, menses and cycle phase lengths, and generalized linear models using Poisson regression with robust variance to assess dichotomous outcomes such as ovulatory function, short luteal phases and presence or absence of follicular or luteal bleeding. Cycles were stratified by the presence or absence of any sexual intercourse, while adjusting for women's parity, age, recent oral contraceptive use and breast feeding.

MAIN RESULTS AND THE ROLE OF CHANCE: Most women were <30 years of age (75.5%; median 27, interquartile range 24–29), non-Hispanic white (88.1%), with high socioeconomic indicators and nulliparous (70.9%). Cycles with no sexual intercourse compared to cycles with at least 1 day of sexual intercourse were shorter (29.1 days (95% CI 27.6, 30.7) versus 30.1 days (95% CI 28.7, 31.4)), had shorter luteal phases (10.8 days (95% CI 10.2, 11.5) versus 11.4 days (95% CI 10.9, 12.0)), had a higher probability of luteal phase deficiency (<10 days; adjusted probability ratio (PR) 1.31 (95% CI 1.00, 1.71)), had a higher probability of 2 days of premenstrual spotting (adjusted PR 2.15 (95% CI 1.09, 4.24)) and a higher probability of having two or fewer days of peak-type (estrogenic) cervical fluid (adjusted PR 1.49 (95% CI 1.03, 2.15)).

LIMITATIONS, REASONS FOR CAUTION: Our study participants were geographically dispersed but relatively homogeneous in regard to race, ethnicity, income and educational levels, and all had male partners, which may limit the generalizability of the findings. We cannot exclude the possibility of undetected subfertility or related gynecologic disorders among some of the women, such as undetected endometriosis or polycystic ovary syndrome, which would impact the generalizability of our findings. Acute illness or stressful events might have reduced the likelihood of any intercourse during a cycle, while also altering cycle characteristics. Some cycles in the no intercourse group may have actually had undocumented intercourse or other sexual activity, but this would bias our results toward the null. The Creighton Model FertilityCare System (CrM) discourages use of barrier methods, so we believe that most instances of intercourse involved exposure to semen; however, condoms may have been used in some cycles. Our dataset lacks any information about the occurrence of female orgasm, precluding our ability to evaluate the independent or combined impact of female orgasm on cycle characteristics.

WIDER IMPLICATIONS OF THE FINDINGS: Sexual activity may change reproductive hormonal patterns, and/or levels of reproductive hormones may influence the likelihood of sexual activity. Future work may help with understanding the extent to which exposure to seminal fluid, and/or female orgasm and/or timing of intercourse could impact menstrual cycle function. In theory, large data sets from women using menstrual and fertility tracking apps could be informative if women can be appropriately incentivized to record intercourse completely. It is also of interest to understand how cycle characteristics may differ in women with gynecological problems or subfertility.

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Key words: menstrual cycle / fecundability / fertility / ovulation / peak day / cervical fluid / premenstrual spotting / sexual intercourse

WHAT DOES THIS MEAN FOR PATIENTS?

This study looks at whether there is a difference in bleeding, spotting or vaginal discharge patterns in cycles with no intercourse compared to cycles with at least one occurrence of intercourse for heterosexual women aged 18–40 years old.

While sexual intercourse is required for a natural conception, it may also play role in improving the cycle function.

In this study, we assessed 2564 charted cycles of 530 women who received training on how to record their daily vaginal discharges and any act of sexual intercourse. We found that cycles with at least one occurrence of intercourse compared to cycles without intercourse had less premenstrual spotting and a better mucus secretion quality needed for a successful conception.

Introduction

Human females are spontaneous ovulators, experiencing an LH surge and ovulation cyclically, independent of copulation (Adams *et al.*, 2016; Pavličev and Wagner, 2016). However, evidence suggests that in some placental mammals, environmental influences, including copulation, impact the timing of ovulation (Adams *et al.*, 2016; Pavličev and Wagner, 2016). Across various species, it is unclear whether copulation-induced ovulation is a result of physical stimulation of the genitalia during copulation, the endocrinological and neurological changes that comprise female orgasm (Pavličev and Wagner, 2016; Rabinerson *et al.*, 2018), ovulation-inducing factors in seminal plasma or a combination of these factors (Adams *et al.*, 2016; Pavličev and Wagner, 2016).

Studies in humans have found changes in female reproductive hormones attributable to copulation (Prasad *et al.*, 2014), but the literature lacks work to evaluate the specific relationship of sexual intercourse to menstrual cycle characteristics. In this study, we aimed to investigate menstrual cycle characteristics, including ovulation, follicular and luteal phase lengths, bleeding patterns, and cervical mucus secretion patterns between cycles with and without sexual intercourse in regularly menstruating, sexually active, heterosexual women, with no history of subfertility.

Materials and methods

Sample

We conducted a pooled analysis of three cohorts of heterosexually active couples who received instruction in the Creighton Model FertilityCare system (CrM) through CrM centers across USA and Canada: (i) '*Creighton Model Effectiveness, Intentions, and Behaviors Assessment*' (CEIBA, 2009–2013, 17 CrM centers in 13 US states and Toronto, Canada; Stanford and Porucznik, 2017), a prospective cohort of women without known subfertility, aimed to evaluate and classify pregnancy rates and pregnancy intentions during use of the CrM; (ii) '*Time to Pregnancy in Normal Fertility*' (TTP, 2003–2006, single CrM center in Utah; Stanford *et al.*, 2014), a randomized trial, which aimed to assess the impact of CrM use on time to pregnancy in couples of proven fertility trying to conceive; and (iii) '*Creighton Model MultiCenter*

Fecundability Study' (CMFS, 1990–1996, 6 CrM centers in four US states; Stanford *et al.*, 2003), a retrospective cohort of presumably fertile and subfertile women using CrM, aimed to assess the relationship between vulvar mucus observations and the day and cycle-specific probabilities of conception. For CEIBA and CMFS, women were required at entry to the study to be seeking to avoid pregnancy (i.e. using CrM for natural family planning to avoid pregnancy); however, they were able at any point during the study follow-up to seek pregnancy (Stanford *et al.*, 2003; Stanford and Porucznik, 2017). All cohort studies were approved by the Institutional Review Board (IRB) at the University of Utah (CEIBA IRB 34487, TTP IRB 7042, CMFS IRB 5246).

Eligibility

From CEIBA, all participants, from TTP, only participants in the CrM intervention group, and from CMFS, only the presumably fertile women met the initial requirement for our study, i.e. women age 18–40 years, no clinical history of subfertility or conditions that may be associated with subfertility, and not breast feeding (TTP and CMFS), or if breast feeding, not doing so exclusively (CEIBA). Having at least one normal menses since the last use of hormonal contraception was required by all these cohorts (Nassaralla *et al.*, 2011; Girum and Wasie, 2018).

Eligible couples contributed a daily diary (CrM chart) for at least one full cycle, and up to 1 year (CEIBA and CMFS) or 7 cycles (TTP). Otherwise, women contributed data until conception, initiation of hormonal contraception, study withdrawal, loss to follow-up or no longer meeting eligibility requirements (Stanford *et al.*, 2003, 2014; Stanford and Porucznik, 2017). The details of assembling the combined dataset have been published elsewhere (Najmabadi *et al.*, 2020), and are summarized in Table I. All women provided informed consent before participating in the studies.

CrM protocol

All these cohorts included women beginning to use the Creighton Model FertilityCare System, a fertility awareness-based method or natural family planning method (Hilgers and Prebil, 1979; Stanford *et al.*, 2003; Tham *et al.*, 2012). Women using the CrM vaginal discharge

Table I Number of cycles and women excluded and included, by cohort: Creighton Model MultiCenter Fecundability Study (CMFS), Time to Pregnancy in Normal Fertility (TTP) and Creighton Model Effectiveness, Intentions, and Behaviors Assessment (CEIBA).

	CMFS (1990–1996)[1]	TTP (2003–2006)[2]	CEIBA (2009–2013)[3]	Total
		Number		
Initial data[a]				
Centers	6	1	17	23[b]
Women	293	50	238	581
Cycles	1827	169	1328	3324
Days	56 076	5235	40 671	101 982
(Excluded cycles)				
Medications impacting cervical mucus				
Women	(1)	(4)	(1)	(6)
Cycles	(17)	(31)	(5)	(53)
Days	(542)	(952)	(175)	(1669)
Streamlined data entry[c]				
Women	(41)	(0)	(4)	(45)
Cycles	(675)	(2)	(30)	(707)
Days	(20 845)	(74)	(964)	(21 883)
Final data				
Centers	6	1	17	23[b]
Women	251	46	233	530
Cycles	1135	136	1293	2564[d]
Days	34 689	4209	39 532	78 430

[a]Original cohorts data description has been published elsewhere.[1–5]
[b]CMFS and CEIBA had one common center: St John's Mercy Hospital—St Louis, Missouri.
[c]These cycles had information about cycle length and estimated day of ovulation, but lacked information about daily bleeding, mucus or intercourse.
[d]Includes 158 (6.2%) conception cycles, dropped from some measurements.
[1]Stanford *et al.* (2003).
[2]Stanford *et al.* (2014).
[3]Stanford *et al.* (2017).
[4]Najmabadi *et al.* (2020).
[5]Najmabadi *et al.* (2021).

recording system record observations for stretch, color and sensation, and the absence or existence of bleeding and bleeding intensity each day in a daily diary (CrM chart). Women are also instructed how to use these observations to identify the estimated day of ovulation (EDO), and the days of potential fertility (Hilgers et al., 1978; Nassaralla et al., 2011; Tham et al., 2012; Manhart et al., 2013; Stanford et al., 2014). This information can be used to time intercourse to avoid pregnancy or to try to conceive (Duane et al., 2022). Whether they seek to avoid pregnancy or to conceive, women are instructed to record each act of intercourse or genital contact daily. The use of barrier methods is discouraged; the use of lubricants is neither encouraged nor discouraged. All CrM charts were on paper and were collected by CrM teachers or study staff at least every month during the first 3 months, and at least every 3 months following (Hilgers and Prebil, 1979; Najmabadi et al., 2020, 2021).

Primary outcomes

Our primary outcomes were a series of menstrual cycle characteristics based on cycle phase lengths, bleeding characteristics and cervical mucus secretion characteristics. We defined cut-off points *a priori* based on prior research or clinical estimates, as reported in prior analyses (Najmabadi et al., 2020, 2021).

We used the peak day of cervical mucus as the EDO and also the last day of the follicular phase. The mucus peak day is the last day in the cycle of any mucus discharge which is clear, stretchy or lubricative (estrogen-stimulated qualities). The peak day as a marker for ovulation has been validated in numerous studies and in reference to serial follicular ultrasound and/or the urinary surge of LH (Fehring, 2002; Porucznik et al., 2014; Ecochard et al., 2015; Stanford, 2015). All cycles in this analysis were reviewed by at least two experts to identify the peak day most likely to reflect the day of ovulation (Najmabadi et al., 2021). We considered cycles without a plausible peak day of cervical mucus to be anovulatory. Supplementary Table SI summarizes primary outcome cycle selection criteria based on ovulatory and/or conception status of the cycle, and the number of cycles and women eligible for each analysis. In the event of conception, subsequent cycles from that woman were censored. There were five CMFS and two CEIBA conception cycles (seven women) with an unknown peak day. To impute these peak days, we used the same ovulation day of the first previous cycle available (Mikolajczyk and Stanford, 2006). For one woman with only one cycle, we used the population median peak day (Najmabadi et al., 2020, 2021).

The cycle length was defined as the number of days from the first day of menstrual bleeding, identified by the woman in the CrM chart, to the last day of the non-conception cycle before the start of the next menses (Reed and Carr, 2000; Mikolajczyk et al., 2010; Nassaralla et al., 2011; Najmabadi et al., 2020, 2021). We defined follicular phase length as the number of days from the first day of menstrual flow through the EDO (inclusive) in ovulatory cycles. Thus, we considered the EDO as the last day of the follicular phase (Reed and Carr, 2000; Nassaralla et al., 2011; Najmabadi et al., 2020, 2021). The luteal phase included days from the first day after the EDO through the last day of menstrual cycle, among ovulatory non-conception cycles.

The first day of each menstrual cycle was the day identified by the woman as the start of the menstrual flow, regardless of the amount of bleeding on that day. Women reported vaginal bleeding each day as heavy, moderate, light, very light (spotting), or brown or black bleeding. No specific guidelines or definitions were given to women for the codes of bleeding intensity. Very light flow and brown or black bleeding were combined and defined as spotting. If bleeding intensity varied through the day, the highest intensity for the day was used. We also calculated an estimate of the intensity of menstrual flow over the first 6 days of the cycle, using a published index (Nassaralla et al., 2011).

All days with mucus that was clear, stretchy or lubricative (estrogen-stimulated qualities) were considered days of peak-type mucus (Hilgers and Prebil, 1979; Fehring, 2002; Bigelow et al., 2004; Ecochard et al., 2015; Najmabadi et al., 2021). Days with any mucus discharge that had none of the characteristics of peak-type mucus were considered days with non-peak mucus (Najmabadi et al., 2021). Each day of each cycle was classified as having peak-type mucus, non-peak mucus or dry (no mucus), with the exception of days with moderate or heavy bleeding.

The quality of cervical mucus prior to and including the EDO was also assessed with an established mucus cycle score index. As the estrogen-stimulated quality of the mucus increases, the total score gets closer to the highest possible of 16 (Hilgers, 1988; Nassaralla et al., 2011).

Potentially fertile days, i.e. days with a significant probability of pregnancy if intercourse were to occur on that day, included most days with any mucus before the peak day (with some exceptions for prolonged unchanging mucus patterns), and the 3 days following any mucus peak day (Hilgers and Prebil, 1979; Najmabadi et al., 2021). All dry days, except those that have non-menstrual spotting or occur within 3 days after a mucus peak day or within 3 days after non-menstrual bleeding or spotting, were considered as non-fertile days (Hilgers and Prebil, 1979; Najmabadi et al., 2021).

Exposure

In our analysis, the primary exposure, intercourse, refers to any cycle with at least one occurrence of vaginal-penile intercourse, regardless of timing during the cycle. We did not have adequate data to differentiate acts of intercourse with and without the use of barrier methods. In a sensitivity analysis, we repeated analyses restricted to women who had at least one cycle with and one cycle without intercourse.

Potential confounders

We conducted adjusted analyses for the following factors as potential confounders that could influence both the probability of intercourse and menstrual cycle function: age ($<$30 years versus $\geq$30 years), parity (nulliparous versus parous women with at least one live birth), partial breast feeding and use of oral contraceptives within 60 days prior to the first day of the cycle.

Statistical analysis

We used descriptive statistics to summarize women's cycle characteristics: cycle phase lengths, parameters of bleeding and cervical mucus, as we reported in prior descriptive analyses (Najmabadi et al., 2020, 2021). We conducted stratified analyses of menstrual cycle parameters with sexual intercourse status. Linear mixed models were used to assess continuous parameters and generalized linear models using Poisson regression with robust variance were used to assess dichotomous outcomes, adjusted for the potential confounders. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC).

Ethical approval

All studies were approved by the University of Utah IRB, as well as local site IRBs.

Results

Participants' characteristics

The combined data comprised 2564 menstrual cycles from 530 women with no known subfertility. The mean number of cycles contributed per woman was 4.8 ± 3.5 cycles (min: 1, 25th: 2, 50th: 4, 75th: 7, max: 15), including 158 (6.2%) conception cycles. Ninety-four women had only one cycle. Most women were <30 years of age (75.5%), with a mean age of 27.1 ± 4.1 years (min: 18, 25th: 24, 50th: 27, 75th: 29, max: 40). Most women were non-Hispanic white (88.1%), married/engaged (89.9%), college graduates (73.8%), employed (78.3%), with a professional level of occupation (50.6%) and had a household income at >200% of federal poverty level (76.4%) in the respective year. Most women (70.9%) were nulliparous (Table II).

Intercourse

Most women (77.4%) had intercourse in all their cycles in the study, while 19.6% of women had a mix of some cycles with and without intercourse, and 3.0% of women had no cycles with intercourse. Among the cycles with intercourse, the mean number of days with sexual intercourse per cycle was 5.4 ± 3.6 (min: 1, 25th: 3, 50th: 5, 75th: 7, max: 24).

Cycle length

In the adjusted analysis, cycles without sexual intercourse compared to cycles with intercourse had shorter mean cycle length (29.1 days (95% CI 27.6, 30.7)) versus (30.1 days (95% CI 28.7, 31.4) (Table III). There was a lower probability of having a long cycle (>35 days) (probability ratio (PR) 0.36 (95% CI 0.18, 0.72)) among cycles without intercourse (Table IV).

Ovulation

Among all cycles, 97.0% had a mucus peak day and were therefore considered ovulatory (95% CI 96.4, 97.7). We did not find any difference in the proportion of ovulatory cycles, comparing cycles without and with sexual intercourse (Table IV).

Follicular phase length

The follicular phase length was essentially the same for cycles without and with intercourse, 18.5 days (95% CI 17.1, 20.0) versus 18.6 days (95% CI 17.4, 19.9) (Table III). The proportion of cycles with a short follicular phase (<10 days) and prolonged follicular phase (>21 days) was 0.8% (95% CI 0.5, 1.2) and 17.7% (95% CI 16.2, 19.2), respectively (Table IV).

Luteal phase length

Cycles without intercourse had a shorter luteal phase length, 10.8 days (95% CI 10.2, 11.5) versus 11.4 days (95% CI 10.9, 12.0) (Table III), and a higher probability of having luteal phase deficiency (<10 days), PR 1.31 (95% CI 1.00, 1.71). Similar effects were seen for luteal phase deficiency with a cut-off of <9 days or <8 days (Table IV).

Table II Demographic and reproductive characteristics, and medical history of study population (530 women without known subfertility, 1990–2013).

Total		**No (%)** **530**
Demographic characteristics		
Age (year)		
<30	400 (75.5)	
•<20		4 (0.8)
•20–24		145 (27.4)
•25–29		251 (47.4)
≥30	130 (24.5)	
•30–34		103 (19.4)
•≥35		27 (5.1)
	Median: 27	
	Mean (standard deviation): 27.1 (4.1)	
	Missing: 0	
Race and ethnicity		
White non-Hispanic		467 (88.1)
Hispanic/Latino		26 (4.9)
Other		33 (6.2)
Missing		4 (0.8)
Marital status		
Engaged		155 (29.3)
Married		321 (60.6)
Single/other		50 (9.4)
Missing		4 (0.8)
Completed education		
High school, vocational or technical school graduate or less		39 (7.4)
Some college		94 (17.7)
College graduate		391 (73.8)
Missing		6 (1.1)
Employed		
Yes		415 (78.3)
No		108 (20.4)
Missing		7 (1.3)
Occupation		
Professional		268 (50.6)
Clerical/sales		58 (10.9)
Homemaker		73 (13.8)
Student		73 (13.8)
Other		50 (9.4)
Missing		8 (1.5)
Income relative to U.S. Federal poverty level, adjusted by year		
<150%		44 (8.3)
150–200%		38 (7.2)
>200%		405 (76.4)
Missing		43 (8.1)

(continued)

Table II Continued

Total	No (%) 530	
Reproductive history		
Age at first menstruation (year)		
≤10	20 (3.8)	
11–14	442 (83.4)	
≥15	60 (11.3)	
Missing	8 (1.5)	
Age at first pregnancy (year)		
Never pregnant	353 (66.6)	
≤19	15 (2.8)	
20–24	73 (13.8)	
25–29	66 (12.5)	
≥30	16 (3.0)	
Missing	7 (1.3)	
Parity		
Nulliparous	376 (70.9)	
1	60 (11.3)	
≥2	89 (16.8)	
Missing	5 (0.9)	
Miscarriage		
None	479 (90.4)	
At least one	43 (8.1)	
Missing	8 (1.5)	
Breast feeding (partial)		
Yes	23 (4.3)	
No	507 (95.7)	
Missing	0 (0.0)	
Recent use of oral contraceptives (OCs)		
≤60 days prior to 1st day of 1st cycle in study	90 (17.0)	
>60 days prior to 1st day of 1st cycle in study or did not use OCs within past year	427 (80.6)	
Missing	13 (2.5)	
Medical history		
Pelvic infection or sexually transmitted infection		
Yes	26 (4.9)	
No	502 (94.7)	
Missing	2 (0.4)	
Vaginal infection, including yeast infection		
Yes	205 (38.7)	
No	324 (61.1)	
Missing	1 (0.2)	
Cervical procedure, including cryotherapy, loop electrical excision, cauterization, colposcopy, biopsy		
Yes		14 (2.6)
No		516 (97.4)
Missing		0 (0.0)
Obstetrical/gynecological surgery		
One or more procedures		44 (8.3)
•Caesarean section	29 (5.5)	
•Dilation and curettage	11 (2.1)	
•Other, including laparoscopy	8 (1.5)	
No procedure		486 (91.7)
Missing		0 (0.0)
Current smoking[a]		
Yes		16 (5.7)
No		252 (90.3)
Missing		11 (3.9)
Current alcohol consumption[a]		
Yes		197 (70.6)
No		71 (25.5)
Missing		11 (3.9)

[a]Total 279, not available for Creighton Model MultiCenter Fecundability Study (CMFS, 251 women) (see Table I).

Menstrual flow and spotting

The mean duration of menstrual flow was essentially the same for cycles without and with intercourse, 6.1 days (95% CI 5.8, 6.4) and 6.2 days (95% CI 5.9, 6.5), respectively (Table III). In the adjusted analysis, cycles with no intercourse had a higher probability of having premenstrual spotting on the last day or last two consecutive days of the cycle, PR 2.16 (95% CI 1.10, 4.23), and (PR 2.15 (95% CI 1.09, 4.24)), respectively (Table IV).

Cervical mucus

We did not find any significant differences between cycles without and with intercourse for the mean number of days with peak-type (estrogenic quality) mucus, 7.6 days (95% CI 6.6, 8.5) versus 7.5 days (95% CI 6.6, 8.3), or for the mean cervical mucus cycle score 8.5 (95% CI 7.7, 9.2) versus 8.5 (95% CI 7.9, 9.2) (Table III). However, in adjusted analysis, cycles with no intercourse had a higher probability of having ≤2 days of peak-type mucus, PR 1.49 (95% CI 1.03, 2.15) (Table IV).

Summary characteristics

Supplementary Table SII summarizes all menstrual cycle characteristics across the entire study population, including mean and percentile distributions.

Table III Adjusted mean of self-reported cycle characteristics in 530 women, stratified by sexual intercourse (SI).[a]

		Unadjusted		Adjusted[b]	
	Total	No SI	SI ≥1	No SI	SI ≥1
Number of women[c]	**530**	**120**	**514**	**120**	**514**
Number of cycles[c]	**2564**	**199**	**2365**	**199**	**2365**
			Mean (95% CI)		
Length characteristics					
Cycle length	30.7 (30.2, 31.2)	29.8 (28.9, 30.7)	30.7* (30.2, 31.2)	29.1 (27.6, 30.7)	30.1* (28.7, 31.4)
Length of follicular phase	18.8 (18.3, 19.3)	18.7 (17.8, 19.6)	18.8 (18.3, 19.3)	18.5 (17.1, 20.0)	18.6 (17.4, 19.9)
Length of luteal phase	11.7 (11.5, 11.9)	11.2 (10.8, 11.6)	11.8** (11.6, 12.0)	10.8 (10.2, 11.5)	11.4** (10.9, 12.0)
Menstrual bleeding/spotting					
Duration of menses	6.2 (6.1, 6.3)	6.1 (6.0, 6.3)	6.2 (6.1, 6.4)	6.1 (5.8, 6.4)	6.2 (5.9, 6.5)
Menstrual flow score	6.1 (6.0, 6.2)	6.1 (5.9, 6.3)	6.1 (6.0, 6.2)	6.2 (5.9, 6.5)	6.2 (5.9, 6.5)
Non-menstrual bleeding/spotting					
Bleeding or spotting in follicular phase[d]	2.2 (1.9, 2.5)	1.4 (−0.7, 3.6)	2.3 (1.7, 2.8)	0.8 (−1.7, 3.4)	1.6 (0.1, 3.1)
Bleeding or spotting in luteal phase[d]	2.5 (2.1, 2.8)	2.5 (1.3, 3.7)	2.4 (2.0, 2.9)	2.2 (0.7, 3.8)	2.2 (1.1, 3.3)
Cervical mucus characteristics					
Days of peak-type (estrogenic) mucus	6.4 (6.1, 6.8)	6.5 (5.9, 7.0)	6.4 (6.1, 6.8)	7.6 (6.6, 8.5)	7.5 (6.6, 8.3)
Days of non-peak-type mucus	5.4 (4.9, 5.8)	5.0 (4.4, 5.7)	5.4 (5.0, 5.9)	5.6 (4.4, 6.9)	6.0 (4.9, 7.2)
Dry days	18.8 (18.2, 19.4)	18.6 (17.7, 19.5)	18.8 (18.2, 19.4)	16.4 (14.7, 18.1)	16.7 (15.1, 18.2)
Cervical mucus cycle score	8.2 (7.9, 8.4)	8.0 (7.6, 8.5)	8.2 (7.9, 8.5)	8.5 (7.7, 9.2)	8.5 (7.9, 9.2)
Fertility characteristics					
Potentially fertile days	12.5 (12.1, 13.0)	12.7 (11.9, 13.4)	12.5 (12.1, 13.0)	14.2 (12.9, 15.5)	14.0 (13.0, 15.1)
Non-fertile days	16.8 (16.4, 17.3)	16.1 (15.3, 16.9)	16.9* (16.4, 17.4)	14.1 (12.8, 15.5)	14.9* (13.7, 16.1)

[a]Linear mixed models were used to generate least square means.
[b]Adjusted for age, parity, partial breast feeding and recent use of oral contraceptives (see Table II).
[c]Number of cycles and women per variable is available in Supplementary Table SI.
[d]Among cycles with follicular or luteal phase bleeding or spotting. Days of bleeding or spotting in follicular phase have been counted from the day after menses through ovulation day.
*$0.01 < P < 0.05$.
**$P < 0.01$.

Sensitivity analysis

We conducted sensitivity analyses, repeating all analyses limited to women who contributed cycles both without and with sexual intercourse in the study (n = 104 women, 733 cycles, of which 169 without intercourse). The findings from these analyses were all consistent with the primary analyses. Even with a smaller sample size, most of the findings remained statistically significant, including the greater likelihood of a luteal phase <10 days, cycles ≤2 days of peak-type mucus, and premenstrual spotting (data not shown).

Table IV Proportions and risk ratios for selected cycle characteristics without intercourse compared to cycles with intercourse (referent).[a,b]

	Total proportion	Unadjusted	Adjusted[c]
Number of cycles	**2564**	**None vs >=1 SI**	**None vs >=1 SI**
Number of women	**530**	**PR (95% CI)**	**PR (95% CI)**
Ovulation			
Ovulatory cycles	97.0 (96.4, 97.7)	0.99 (0.96, 1.02)	0.99 (0.96, 1.03)
Length characteristics			
Short cycle (<23 days)	1.2 (0.7, 1.6)	2.65 (0.83, 8.40)	1.96 (0.55, 6.91)
Long cycle (>35 days)	10.8 (9.5, 12.0)	0.44 (0.23, 0.83)*	0.36 (0.18, 0.72)**
Short follicular phase (<10 days)	0.8 (0.5, 1.2)	1.28 (0.28, 5.91)	1.06 (0.18, 6.43)
Prolonged follicular phase (>21 days)	17.7 (16.2, 19.2)	0.99 (0.71, 1.38)	0.94 (0.66, 1.34)
Short luteal phase (<10 days)	18.2 (16.6, 19.8)	1.33 (1.02, 1.74)*	1.31 (1.00, 1.71)*
Short luteal phase (<9 days)	10.5 (9.3, 11.8)	1.47 (1.02, 2.12)*	1.40 (0.98, 2.00)
Short luteal phase (<8 days)	6.4 (5.4, 7.3)	1.79 (1.17, 2.74)**	1.64 (1.07, 2.74)*
Prolonged luteal phase (>16 days)	4.0 (3.2, 4.7)	0.16 (0.02, 1.24)	0.16 (0.02, 1.19)
Menstrual bleeding			
Short menstrual flow (<4 days)	1.2 (0.8, 1.6)	2.64 (0.84, 8.30)	2.31 (0.64, 8.35)
Prolonged menstrual flow (>8 days)	6.2 (5.3, 7.1)	0.85 (0.46, 1.54)	0.84 (0.46, 1.53)
Non-menstrual bleeding/spotting			
Bleeding or spotting in follicular phase[c]	9.8 (8.6, 10.9)	0.84 (0.46, 1.53)	0.87 (0.48, 1.58)
Bleeding or spotting in luteal phase	8.0 (6.9, 9.1)	0.93 (0.59, 1.47)	0.94 (0.60, 1.50)
Premenstrual spotting in last day of cycle	2.3 (1.7, 2.9)	1.88 (1.01, 3.51)*	2.16 (1.10, 4.23)*
Premenstrual spotting in last 2 consecutive days of cycle	2.2 (1.6, 2.7)	1.99 (1.00, 3.96)*	2.15 (1.09, 4.24)*
Cervical mucus characteristics			
Cycles with ≤2 days of peak-type mucus	12.2 (10.9, 13.6)	1.53 (1.06, 2.20)*	1.49 (1.03, 2.15)*
Cycles with cervical mucus cycle score ≤4.0	20.4 (18.8, 22.0)	1.11 (0.87, 1.41)	1.06 (0.83, 1.35)
Fertility characteristics			
Cycles with ≤9 potentially fertile days	33.7 (31.8, 35.6)	1.09 (0.89, 1.34)	1.03 (0.84, 1.27)

[a]Number of cycles and women per variable is available in Supplementary Table SI.
[b]Generalized linear mixed models were used to generate risk ratios and 95% confidence intervals.
[c]Days of bleeding or spotting in follicular phase have been counted from after the end of menses through ovulation day.
*0.01 < P < 0.05.
**P < 0.01.
PR, prevalence ratio; SI, sexual intercourse.

Discussion

Principal findings

We investigated the relationship between sexual intercourse and menstrual cycle characteristics among 2564 cycles in 530 heterosexually active premenopausal women (median age 27), without any known subfertility. We found an association between no intercourse in the cycle and a shorter luteal phase, a higher likelihood of a luteal phase <10 (or <9 or <8) days, a higher likelihood of premenstrual spotting, and a higher probability of having ≤2 days of peak-type (estrogenic) cervical fluid.

Clinical implications

The differences in cycle parameters are relatively subtle and may not have direct clinical implications. Nevertheless, follicular development, as assessed by preovulatory follicular size in the ovary, is positively related to levels of estradiol before ovulation (which in turn influences cervical mucus quality), and it also positively influences corpus luteum function and levels of progesterone after ovulation (which in turn influences luteal phase length, and perhaps whether there is spotting before the menses; Blackwell et al., 2013, 2018; Abdulla et al., 2018). Therefore, it may be worth considering whether in some instances, an absence of sexual intercourse may contribute to a short luteal phase, luteal phase defect, fewer days of peak-type mucus or premenstrual spotting. Like other investigators, we found a substantial variability of the luteal phase length overall (Blaicher et al., 1999; Duijkers et al., 2005; Jones and Lopez, 2006; Fritz and Speroff, 2011).

Cycles with fewer days of peak-type mucus have lower potential fecundability (Stanford et al., 2003; Bigelow et al., 2004). We cannot exclude entirely the possibility that seminal fluid or arousal fluid associated with sexual intercourse could sometimes be recorded as cervical fluid. However, the CrM has instructions to distinguish arousal fluid and eliminate seminal fluid after intercourse (Hilgers *et al.*, 2004). We also did not have any data for the use of lubricants.

Cycles with no intercourse had a significantly higher probability of premenstrual spotting. Speculatively, premenstrual spotting might be a marker for lower fecundability, as it has also been associated with the presence of endometriosis (Heitmann *et al.*, 2014).

Research implications

In a prospective cohort of 259 regularly menstruating women aged 18–44 years with self-reported vaginal-penile intercourse in 1–2 cycles (the BioCycle Study), Prasad *et al.* found associations between any intercourse and higher levels of progesterone, estradiol and midcycle LH, but only when compared to women who reported never having had sexual intercourse. They also found that estrogen, LH and testosterone levels were higher on days of intercourse and the day before, but not the day after. They suggested their findings could be interpreted in both directions for causality: higher hormones increasing the probability of sexual intercourse, and/or sexual intercourse (or at least ever having sexual intercourse) increasing the level of reproductive hormones (Prasad *et al.*, 2014). While our study population included only sexually experienced women, our findings could also be consistent with an influence in either direction between sexual intercourse, reproductive hormones and impacts of the hormones on luteal phase length, premenstrual spotting and days of estrogenic mucus (Ecochard *et al.*, 2017; Richards, 2018). However, due to other non-biological precursors that can influence human sexual behavior (Salonia *et al.*, 2010), assessing hormonal influences on female sexuality is complex. Presumably constant male sexual interest across the female cycle may mask the effects of cyclic changes in female sexual desire that might be triggered by her hormones (Caruso *et al.*, 2014).

We did not find an increased probability of sporadic anovulatory cycles (based on cervical mucus peak day) among cycles with compared to those without sexual intercourse. This finding is in agreement with the BioCycle Study (where ovulation was defined by peak serum progesterone $\leq$5 ng/ml and no observed serum LH peak) in cycles without or with intercourse among sexually active participants. However, in the BioCycle study, sexually active women compared to sexually inactive women had lower odds of sporadic anovulation (adjusted risk ratio 0.34 (CI 0.16–0.73); Prasad *et al.*, 2014).

Limitations and strengths

This study has some limitations. Our study participants were geographically dispersed but relatively homogeneous with regards to race, ethnicity, income and educational levels, and all had male partners, which may limit the generalizability of the findings. A potential confounding factor would be acute illness or stressful events that might reduce the events of intercourse during a cycle to zero, and also might disturb or alter cycle characteristics. Only one of the cohorts (TTP) had information noted systematically for daily stress and stressful events; in a prior analysis of that cohort, higher stress did not cause reduced fecundability, but the impact on cycle characteristics was not specifically studied (Park *et al.*, 2019).

In cycles with unrecognized conception and very early pregnancy loss, there is a possibility of an apparently longer luteal phase. We cannot rule this out as a possible explanation for a longer luteal phase in cycles with intercourse (Wilcox *et al.*, 1999; Promislow *et al.*, 2007). However, this would not be a possible explanation for any changes in cervical fluid secretion.

Although the cervical mucus peak day is a reliable marker of ovulation, it is not as precise as serial follicular ultrasound, or some hormonal measures, which introduces imprecision in the outcome measures (Ecochard *et al.*, 2001; Stanford *et al.*, 2020). We cannot exclude the possibility of undetected subfertility or related gynecologic disorders among some of the women, such as undetected endometriosis or polycystic ovary syndrome, which would impact generalizability of our findings. However, it is not clear whether or how including more cycles from subfertile women would impact our findings; the generalized linear model does account for the number of cycles contributed per woman. Some cycles in the no intercourse group may have actually had undocumented intercourse or other sexual activity, but this would bias our results toward the null. The CrM discourages use of barrier methods, so we believe that most instances of intercourse involved exposure to semen. However, we did not have information to detect consistently cycles where barriers may have been used. Some studies suggest that seminal plasma may have an impact on female reproductive function (Robertson and Sharkey, 2016; Hopkins *et al.*, 2017). Further research assessing the impact of seminal fluid exposure is recommended.

Our dataset lacks any information about the occurrence of female orgasm, precluding our ability to evaluate the independent or combined impact of female orgasm on cycle characteristics. From an evolutionary perspective, human female orgasm does not seem to be essential for ovulation and reproductive success. Still, clitoral stimulation and female orgasm may have some residual influence on ovulation timing in humans (Pavličev and Wagner, 2016). In a recent small study of 11 healthy women, using neuro-imaging technics, researchers showed that compared to a resting state, orgasm increases blood supply and elevates pituitary activation, which leads to higher plasma concentrations of oxytocin and prolactin (Blaicher *et al.*, 1999), which may facilitate ovulation and enhance sperm and oocyte transport (Huynh *et al.*, 2013).

This large study has some key strengths, including prospectively collected data on bleeding, cervical mucus and intercourse in daily diaries. The inclusion of multiple cycles per woman in the study allowed us to assess within-woman variability across cycles without and with intercourse (Harlow and Ephross, 1995). The standardized protocol for evaluating daily bleeding and cervical fluid (CrM), allowed us to describe detailed menstrual characteristics simultaneously, and our sample size allowed adjustment for age, parity, recent hormonal contraceptive use and breast feeding.

Conclusions

We found evidence of cycle characteristics suggesting lower fecundability among cycles with no intercourse, compared with cycles with intercourse, among sexually active women without any known subfertility. These included shorter luteal phases, more cycles with luteal phase $<$10 days, more cycles with premenstrual spotting, and more cycles with two or fewer days of peak-type mucus (high-quality estrogen-stimulated cervical fluid). Sexual activity may change reproductive hormonal patterns, and/or levels of reproductive hormones may influence the likelihood of sexual activity. Future work may help understand the extent to which exposure to seminal fluid, and/or female orgasm and/or timing of intercourse could impact menstrual cycle function. In theory, large data sets from women using menstrual and fertility tracking apps could be informative if women can be appropriately incentivized to record intercourse completely (Bull *et al.*, 2019; Faust *et al.*, 2019). It is also of interest to understand how cycle characteristics may differ in women with gynecological problems or subfertility.

Supplementary data

Supplementary data are available at *Human Reproduction Open* online.

Data availability

Data are available from authors upon reasonable request, subject to institutional and research ethics (IRB) approval.

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Authors' roles

S.N. and J.B.S. conceived of the study and wrote the manuscript. S.N. conducted all of the analyses. K.C.S. and M.J.E. advised on the statistical analyses. S.N., J.B.S., K.C.S., S.E.S. and C.A.P. revised the manuscript for important intellectual content. All authors approved the final manuscript.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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