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Women Who are Married or Living as Married have Higher Salivary Estradiol and Progesterone than Unmarried Women

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Abstract

Objectives—Extensive research has demonstrated that marriage and parenting are associated with lower testosterone levels in men, however, very little is known about associations with hormone concentrations in women. Two studies have found lower testosterone in relation to pair-bonding and motherhood in women, with several others suggesting that estradiol levels are lower among parous women than nulliparous women. Here, we examine estradiol and progesterone concentrations in relation to marriage and motherhood in naturally cycling, reproductive age women.

Methods—In 185 Norwegian women, estradiol and progesterone concentrations were assayed from waking saliva samples collected daily over the course of a menstrual cycle. Cycles were aligned on day 0, the day of ovulation. Mean periovulatory estradiol (days –7 to +6) and luteal progesterone (day +2 to +10) indices were calculated. Marital status and motherhood (including age of youngest child) were reported in baseline questionnaires. Multivariable linear regression models were used to examine associations between ovarian hormones, marital status, and motherhood.

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Results—Women who were married or living as married had higher estradiol than unmarried women ($\beta = 0.19$; 95% CI: 0.02, 0.36) and higher luteal progesterone as well ($\beta = 0.19$; 95% CI: -0.01, 0.39). There were no notable differences in hormone levels in relationship to motherhood status.

Conclusions—Our results indicate that ovarian steroid hormones may be higher among women who are married or living as married, and suggest several possible explanations, however, additional research is needed to elucidate any causal relationships.

In the past decade, there has been great interest in hormonal correlates of mating and parenting in humans. In men, a sizeable literature has accrued showing that testosterone levels are typically lower in married men and men with children as compared to men who are single, childless, or both (Booth and Dabbs, 1993; Gettler et al., 2011a, 2011b; Gray et al., 2002, 2006; Kuzawa et al., 2009; Muller et al., 2009). These results are consistent with findings from other species (most notably birds) and suggest that in males, the modulation of testosterone in relation to mating and parenting may be adaptive (Reburn and Wynne-Edwards, 1999; Wingfield et al., 1990; Ziegler, 2000). Although this question has received less attention in women, at least two studies have shown that marriage and parenthood are associated with lower testosterone in women as well (Barrett et al., 2013; Kuzawa et al., 2010). These results are less readily interpretable, however, because in contrast to its well-characterized functions in men, the role of testosterone in relation to female reproductive physiology and behavior is unclear.

Testosterone may contribute to female fecundity and mating behaviors (Lebbe and Woodruff, 2013; van Anders et al., 2007), however, its importance is over-shadowed by two other ovarian hormones, estradiol and progesterone, both of which are central to female reproductive success. Estradiol levels are correlated with the size of the growing dominant follicle, oocyte quality, endometrial thickness, and cervical mucus penetrability (Bakos et al., 1994; Eissa et al., 1986; Roumen et al., 1982) and progesterone contributes by further preparing the endometrium for potential pregnancy (Clancy, 2009; Santoro et al., 2000). Not surprisingly, therefore, both within and across women, the concentrations of estradiol and progesterone in a cycle are good indicators of fecundability, the probability of conception in that cycle (Baird et al., 1997; Lipson and Ellison, 1996; Venners et al., 2006). A great deal of research has examined how estradiol and progesterone respond to ecological cues in the short-term and this work demonstrates that when conditions are suboptimal for investment in an energetically expensive pregnancy (for instance, when food is scarce or physical demands are high), ovarian hormones are down-regulated (Bentley et al., 1998; Jasienska and Ellison, 2004; Panter-Brick et al., 1993). In addition to such short term cues, there may be determinants of ovarian hormone levels operating over on longer time scale. For instance, it is hypothesized that developmental trajectories initiated in response to the early environment may contribute to ovarian steroid concentrations years later (Apter et al., 1989; Clancy et al., 2013; Finstad et al., 2009). As with testosterone, moreover, it is possible that estradiol and progesterone concentrations in adulthood are associated with sociodemographic factors (Barrett et al., 2013; Kuzawa et al., 2010). Surprisingly, very little is known about the extent to which estradiol and progesterone vary in relation to marital status and motherhood in adult women.

Several studies have found that estradiol concentrations (measured in single serum samples) are lower in mothers than non-mothers midcycle (Bernstein et al., 1985) as well as in multiparous versus primiparous women during pregnancy (Arslan et al., 2006; Toriola et al., 2011). In addition, we recently reported that in a large cohort of cycling women, urinary estradiol metabolite concentrations (as measured daily for up to eight menstrual cycles) are lower in recent mothers (with a child ≤ 3 years of age) than in mothers of older children (youngest child >3 years of age) and non-mothers. Among mothers in that study, furthermore, urinary estradiol metabolite concentrations were positively associated with the age of the youngest child, adjusting for covariates. No associations between progesterone concentrations and motherhood status were found (Barrett et al., in press). None of these studies assessed whether relationship status was associated with ovarian hormone concentrations, however, possibly because study design for time to pregnancy or pregnancy cohort studies often requires women to be partnered. In light of studies demonstrating lower testosterone among married or partnered women, furthermore, it may be relevant to consider whether marriage is associated with a broader down-regulation of ovarian hormone production, including estradiol and progesterone. Therefore, the aim of the current analysis was to better understand the hormonal correlates of marriage and motherhood, by investigating the extent to which cycle-long salivary estradiol and progesterone concentrations vary in relation to marital status and motherhood in a cohort of naturally cycling, reproductive age women.

METHODS

Study population and design

From 2000 to 2002, posters and local advertisements were used to recruit 207 women from Tromsø, Norway into the Energy Balance and Breast Cancer Aspects (EBBA-I) study. EBBA-I was designed to look at the relationship between lifestyle factors, ovarian hormones, and breast cancer risk. Eligible women were 25–35 years of age, with self-reported regular menstrual cycles. Women who were currently (or had been within the last 6 months) pregnant, breast-feeding, or taking hormonal contraceptives, were excluded from participating, as were women with a history of infertility, reproductive disorders, or chronic illness. At the start of their next menstrual cycle, consented subjects underwent an intake examination during which they completed a baseline questionnaire, including items on demographics, reproductive history, and lifestyle. Women reported their marital status from the following five choices: single, married/living as married, widowed, divorced/separated, or other. Subjects also reported on whether they had any children and if so, the ages of those children. Women were asked about their age, current smoking habits, current alcohol use, history of use of hormonal contraceptives, and their level of physical activity. Although physical activity was assessed in great detail, self-reported general activity level (on a scale of 1–4: 1 = sedentary or low activity, 2 = moderate activities at least 4 hours per week, 3 = hard activities to keep fit for at least 4 hours per week; 4 = hard training or exercise for competition several times per week) provided a good proxy for overall activity level (Emaus et al., 2008). At the intake exam, subjects also underwent a brief physical exam, during which height and weight were measured. Body mass index (BMI) was later calculated as weight (kg)/height (m^2). The study population and methods are described in greater detail

elsewhere (Furberg et al., 2005). The Institutional Review Boards of all participating institutions and the Norwegian Data Inspectorate approved the study prior to the start of recruitment and written consent was obtained from all subjects prior to starting study activities.

Saliva sample collection and hormone assay

As part of study activities, starting with the first day of bleeding in the index menstrual cycle and ending with the first day of bleeding in the next menstrual cycle, subjects collected a daily waking saliva sample at home according to protocols published elsewhere (Lipson and Ellison, 1989). Following collection, samples were sent to the Reproductive Ecology Laboratory at Harvard University where 17β -estradiol was assayed in samples from reverse cycle days -5 to -24 (relative to the first day of bleeding in the next cycle) and progesterone was assayed in samples from reverse cycle days -1 to -14. Samples were run in duplicate and all hormone concentrations were determined using I-125 based radioimmunoassay kits (Diagnostic Systems Laboratories, Webster, TX), with slight modifications described elsewhere (Furberg et al., 2005).

To align cycles, the day of ovulation was determined by identifying the second of the two consecutive days between which the greatest midcycle (days -18 to -12) drop in estradiol occurred (Lipson and Ellison, 1996). The estradiol “drop day” approximates the day of ovulation and all cycles were aligned based on the drop day, designated cycle day “0.” As such, days with a negative sign occurred prior to ovulation and were in the follicular phase, whereas days with a positive sign occurred after ovulation and were in the luteal phase. Using this daily hormone data, we calculated two indices: (1) mean estradiol (days -7 to +6) and (2) mean luteal progesterone (days +2 to +10). These intervals roughly approximate the peak periods of ovarian steroid production for these two hormones. Outside of these periods, hormone production was often much lower and for many women, values fell below the sensitivity limit of the assays (4 pmol/L for estradiol, 13 pmol/L for progesterone). Within those periods, estradiol and progesterone concentrations were at or below the sensitivity limit in 6% and 3% of the samples assayed, respectively, and those samples were assigned the sensitivity limit as their value. Fourteen subjects had no discernable day of ovulation and thus were excluded because their hormonal profiles could not be aligned. For estradiol, the average intra-assay variability was 9%. Interassay variability was 23% for the low pools and 13% for the high pools. For progesterone, the average intra-assay variability was 10%. Interassay variability was 19% for the low pools and 12% for the high pools.

Imputation of missing ovarian hormone data

As subjects were asked to collect daily saliva samples on their own over a full menstrual cycle, some women were missing at least one sample. After plotting the subject-specific distribution of observed hormone data, for estradiol analyses, any subject with values that were missing for more than 5 days within the specified interval was excluded and for progesterone analyses, any subject with values that were missing for more than 4 days of data during the specified interval was excluded. For the remaining women, rather than ignoring the missing data, we used a simple imputation method: (a) data that were missing at the beginning or end of the cycle intervals being considered were assigned the value of the

nearest neighbor; (b) data that were missing in between observed values were assigned the geometric mean of the rightmost and leftmost neighbors. Finally, each subject's imputed and observed hormone values were averaged on the logarithmic scale to yield the relevant hormonal index (luteal progesterone or total estradiol). Ultimately, 34% of subjects had at least one estradiol value imputed and 29% had at least one progesterone value imputed. No subject included in the current analyses was missing data for more than 3 days in a row. Including women with imputed hormone values, 184 women had complete data needed for the current progesterone analyses and 185 had complete data for the estradiol analyses.

Statistical analysis

Whenever possible, we operationalized variables to remain consistent with our previous work (Barrett et al., 2013, in press). To that end, women who reported being single or divorced/separated were designated "unmarried" and those who reported being married or living as married were considered "married" (Barrett et al., 2013). Similarly, for our motherhood analyses, we created two dummy variables to distinguish between our three groups of interest, (non-mothers, mothers with a child ≤ 3 years of age, mothers with no child ≤ 3) (Barrett et al., 2013, in press), as we could not include nulliparous women if we considered age of youngest child continuously. Collectively, we refer to these variables as "motherhood status." For physical activity, as few women reported regularly engaging in intense activity, levels 3 and 4 were combined into a single, high activity group, as was done in previous research in this population (Emaus et al., 2008). A small number of women were missing relevant data and were thus excluded from analyses: history of oral contraceptive use ($n = 1$); progesterone levels (>4 days; $n = 2$); and estradiol levels (>5 days; $n = 1$). In addition, six women who self-reported their marital status as "other" were excluded from the analyses.

We first looked at descriptive statistics (frequencies, means, standard deviations, maxima, minima, and quartiles) for all variables under consideration, for the whole cohort as well as stratified by whether the subject had complete ovarian hormone data. We then conducted bivariate analyses, looking at correlations and plots among the continuous variables. Finally, we conducted a series of multivariable analyses. In the primary set of analyses, we examined whether marriage and motherhood status (non-mothers; mothers with a child ≤ 3 years of age; mothers with no child ≤ 3 years of age) predicted concentrations of the ovarian steroids, estradiol and progesterone. Due to non-normality, estradiol and progesterone data were natural log-transformed to better fit linear regression assumptions. In addition to marital status (married/unmarried) and our two motherhood status variables, based on the existing literature, we selected the following variables *a priori* for inclusion in all models: maternal age, BMI, current smoking status (any/none), current alcohol use (any/none), history of use of hormonal contraceptives (any/none), and physical activity level (low/medium/high). We fit two main linear regression models, one predicting mean (log) estradiol and the other predicting mean (log) progesterone. We also fit a set of models to examine the interaction between marriage and parity (parous/nulliparous) on ovarian steroid concentrations. We then fit secondary linear regression models limited to mothers only to examine the relationship between our outcome variables and age of youngest child (continuous). Knowing that the power of these secondary models would be limited by the small sample of mothers, we

eliminated alcohol use and history of hormonal contraceptive use as covariates from those models, as they did not emerge as predictors of ovarian function in our main models.

Aside from those exceptions, all *a priori* selected covariates were retained in models. To determine if missing ovarian hormone data had an effect on results, we conducted a sensitivity analysis including a binary term for whether a subject had any imputed data (yes/no), irrespective of where in the cycle the hormone data was imputed. For all models, we checked model assumptions of linearity between covariates and outcome and normal distribution of error with constant variance. There were no gross departures from model assumptions, including linearity, homoscedasticity, and normality. Finally, for all analyses, we checked for presence of outliers and influential points. All analyses were done in R (Version 2.9.0) and all *P*-values reported are two-tailed with an alpha-level of 0.05.

RESULTS

On average, the EBBA-I subjects were 30.8 years old and 63 percent were married or living as married (Table 1). Of the unmarried women, nearly all (91%) reported being single, rather than divorced/separated. Fifty-one percent of women were childless, 15% had at least one child age three or younger, and 34% only had children older than age three. Parity ranged from 0 to 5 children. Age of the youngest child ranged from under 1 to nearly 14 years old. Childless women tended to be younger, have lower BMI, and were less likely to be married than mothers. Geometric mean estradiol and progesterone were moderately correlated ($r = 0.53$, $P < 0.01$). Estradiol (but not progesterone) was correlated with age at first birth ($r = -0.23$, $P = 0.03$) as well. Neither estradiol nor progesterone concentrations were significantly correlated with age, age at menarche, or time since last birth. BMI was not correlated with time since last birth ($r = 0.02$). Women with complete hormone data did not differ demographically from women with imputed data. Subjects excluded from analyses due to missing data or lack of a discernable day of ovulation tended to have older children than the women included in the analyses, but were otherwise demographically similar (not shown).

In our primary linear regression models, after adjusting for relevant covariates, women who were married (or living as married) had higher estradiol ($\beta = 0.19$, 95% CI: 0.02, 0.36) and higher progesterone ($\beta = 0.19$, 95% CI: -0.01, 0.39) as compared to unmarried women (Table 2; Fig. 1). By contrast, estradiol and progesterone concentrations were slightly lower in both groups of women with children, as compared to childless women (Table 2). In separate models (not shown), there was no evidence of interaction between marriage and motherhood (parous/nulliparous). Estradiol and progesterone concentrations did not differ, furthermore, between women with children age 3 and under as compared to women who only had older children. In our primary models, aside from marital status, BMI was the only (positive) predictor of estradiol, and no covariate predicted progesterone levels. In our secondary models limited to mothers only, age of youngest child was not related to progesterone or estradiol levels (not shown). In sensitivity analyses, having imputed data did not predict levels of either hormone (not shown). There were no undue outliers or influential observations in any of the models.

DISCUSSION

We found that after adjusting for relevant covariates, among naturally cycling, reproductive age women, women who were married (or living as married) had higher estradiol concentrations on average than unmarried women (20.4% higher) and higher progesterone concentrations as well. We found only slight differences in estradiol or progesterone concentrations in relation to motherhood status or age of youngest child. These results are interesting in light of the limited body of work on this topic and suggest several directions for future study. Surprisingly, we know of no research on marital status or pair-bonding in relation to ovarian hormone concentrations in women, although this is an important question to the extent that ovarian hormones indicate fecundity, and reproductive potential. Our previous work in this population found that serum testosterone concentrations were lower in married than unmarried women (Barrett et al., 2013), whereas for estradiol and progesterone, we have now found the opposite relationship.

Given the cross-sectional nature of this study, it is impossible to ascribe any causal relationships, however, there are several interesting possibilities. One possibility is that marriage or pair-bonding alters hormone levels, such that following pair-bonding, estradiol and progesterone levels increase. This hypothetical scenario could be adaptive if pair-bonding signals more stable, long-term access to resources, including greater potential for biparental care should a conception occur. The altered hormonal milieu among pair-bonded women would represent a physiological shift toward increased odds of conception and paired with the results of previous work showing lower testosterone levels in married or pair-bonded women, a greater investment in pregnancy and parenting, rather than mating effort (Barrett et al., 2013; Kuzawa et al., 2010; van Anders and Watson, 2007).

Alternatively, it is possible that a woman's intrinsic levels of estradiol and progesterone are related to her odds of marrying (or remaining married). That is to say, our results could be explained by women with high estradiol and progesterone being more likely to engage in romantic relationships than women with lower ovarian steroid profiles. To the extent that ovarian steroid profiles are stable over time and indicate fecundity and reproductive potential, they may be linked to signals of attractiveness. For instance, in a cohort of reproductive age Polish women, those with narrow waists and large breasts had 37% higher midcycle salivary estradiol levels than women with other body types, suggesting that body shape may be one honest signal of reproductive fitness (Jasienska et al., 2004). Similarly, in a British study, the faces of women with higher follicular urinary estradiol metabolite levels (and to a lesser extent, luteal progesterone metabolite levels) were rated as more attractive, feminine, and healthy than faces of women with lower estradiol levels (Smith et al., 2006). Thus it is plausible that ovarian hormone concentrations are linked to female attractiveness, however we know of no studies that have taken the next step of looking at whether women with higher levels of ovarian function are more likely to be partnered than women with lower ovarian function. Although our results are suggestive, longitudinal work is needed to fully answer that question.

We cannot rule out the possibility that additional, unmeasured factors that may underlie this relationship as well. These results merit corroboration in a different cohort, and ideally, to

understand the causal and temporal patterns, a naturally cycling population of women must be followed over time through different stages of pair-bonding and motherhood. Although that would be quite challenging in a Western population, the possibility of doing so in a traditional population (with little to no use of hormonal contraception) may be feasible. Examining whether women who are divorced/separated differ from those who have never married may further illuminate the extent to which pair-bonding may have short- or long-lasting effects on ovarian function. Although the sample size of divorced/separated women in our study was too small to draw conclusions ($n = 7$), it is worth noting that their mean ovarian hormone levels were intermediate between women who self-identified as married those who self-identified as single (not shown). If confirmed by other work, our results suggest that marital status may contribute to health and disease, not only through psychological well-being, but through its effects on hormone production. There is evidence that marital status predicts risk of certain illnesses (and may be protective in other cases) and it is possible that differences in lifetime exposure to ovarian steroids may contribute to some of these relationships as well (Cheung, 2000; Ikeda et al., 2007; Khan et al., 2013; Orth-Gomer et al., 2000).

We did not find any notable association between ovarian steroid concentrations and motherhood status, in contrast to our recent findings from a U.S. cohort. In that work, we found that women with young children (< 3 years) had 22% lower follicular urinary estradiol metabolite levels than nulliparous women and there was a strong positive relationship between the age of a woman's youngest child and her estradiol (but not progesterone) levels (Barrett et al., in press). Here, we saw the same direction of effects (namely, lower estradiol and progesterone levels among women with children, compared to nulliparous women), but could not rule out the possibility that the associations were due to chance. In the current study, the number of women with young children (< 3 years) was far smaller ($n = 29$) than in our previous study ($n = 178$), so it is possible that the current study was insufficiently powered to detect such a relationship. Because our sample size was relatively small, furthermore, we were unable to further refine our models to consider differences in ovarian function: (a) among mothers of twins ($n = 5$) and mothers of singletons; (b) among primiparous and multiparous women; and (c) in relation to the number of children (particularly young children) in the household. Given the suppressive effects of lactation on ovarian function (Howie and McNeilly, 1982; Vaggia and Ellison, 2009), in future work, it may also be important to consider time since last birth, time since cessation of lactation, and time since resumption of menses as possible predictors of ovarian function. Other studies have shown relationships between parity and estradiol levels in spot samples (Arslan et al., 2006; Bernstein et al., 1986; Toniolo et al., 1995), further suggesting that a relationship may exist, however ultimately, longitudinal data is needed to follow women through pregnancies and the subsequent postpartum years to provide more definitive answers.

The primary strength of our study is our assessment of ovarian steroid levels. Because we used convenient, noninvasive saliva as our medium for steroid assay, we were able to collect samples daily, allowing us to more accurately capture steroid production across the cycle. This is in contrast to the many clinical studies which (for obvious reasons) must rely on a single (or at best, several) opportunistic serum sample(s) for estradiol and progesterone measurement (Arslan et al., 2006; Bernstein et al., 1985; Dorgan et al., 1995; Musey et al.,

1987; Nagata et al., 2011). In addition, serum levels reflect bound and free steroid levels, whereas salivary hormone levels reflect only the free levels, which are presumably most biologically relevant. Daily biospecimen collection is also feasible through urine (Windham et al., 2002), however, interindividual differences in metabolism may contribute additional, unwanted variation to the resulting conjugated steroid metabolite concentrations (Gann et al., 2001). By limiting our study population to women age 25–35 who were not currently lactating or using hormonal contraception (and had not done so in the previous 6 months), we reduced the possibility that these hormone-related factors could have impacted our results. Lastly, we collected extensive data on known covariates typically associated with ovarian steroid concentrations, including physical activity, allowing us to adjust for them in our analyses.

At the same time, one limitation of our study is that the results may not be generalizable to other populations. We specifically targeted regularly cycling women within a relatively narrow age range, and thus our finding may not reflect relationships that might be found in women who are younger, older, or have irregular cycles. It is possible that in such women, other factors influencing ovarian hormone levels might swamp the relationships we have found here, which are relatively small. In addition, our population is a well-nourished, Western one, and determining whether these relationships hold cross-culturally (similar to the extensive findings on testosterone and parenthood) merits future study. This is a particularly salient question given the notable differences in birth spacing, breast-feeding patterns, and parenting styles in Western populations (such as this one) as compared to traditional, natural fertility populations. Another limitation is that we only collected hormonal data over a single cycle. Although assaying hormone concentrations over a single cycle is quite common in research studies due to practical limitations (Clancy et al., 2013; Furberg et al., 2005; Nunez-De La Mora et al., 2008), it is worth noting that there can be variation in ovarian steroid production within women from cycle-to-cycle, and such variation could have impacted our results (Jasienska and Jasienski, 2008; Windham et al., 2002). It would be preferable to follow women over several cycles to get a more accurate picture of the ovarian steroid production. Additionally, we were unable to distinguish between married and “living as married” (a common alternative in this Northern Norwegian population) and with our relatively small sample size, could not assess marital status in a nuanced way, examining whether separation, divorce, or time since marriage had any effects on the relationships found. Similarly, we did not ask about the sexual orientation of subjects, and it is possible that sexuality was related to both marital status as well as hormone concentrations. However, these are potential avenues for future study in a larger cohort and once again, following the same women longitudinally over time would be most informative.

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Fig. 1. Average daily profiles of ln-transformed estradiol (E2) and progesterone (P) across the menstrual cycle, in naturally cycling married ($n = 117$) and unmarried ($n = 68$) women. Day 0 is the day of ovulation.

TABLE 1

Characteristics of the EBBA-I study population; mean (SD)^a

	Whole cohort (n = 185)	Married women with children (n = 74)	Married women without children (n = 43)	Unmarried women with children (n = 17)	Unmarried women without children (n = 51)
Demographic and anthropometric characteristics					
Age (years)	30.8 (3.0)	32.4 (2.3)	29.1 (2.5)	31.8 (3.2)	29.4 (2.9)
Height (cm)	167.1 (6.6)	167.2 (6.4)	166.7 (7.0)	167.5 (7.8)	167.1 (6.2)
Weight (kg)	68.2 (11.8)	70.5 (12.2)	64.4 (10.6)	67.6 (11.1)	68.1 (11.8)
BMI (kg/m ²)	24.4 (3.8)	25.2 (3.9)	23.1 (3.5)	24.1 (3.2)	24.4 (3.8)
Reproductive characteristics					
Age at menarche (years)	13.1 (1.4)	13.1 (1.4)	13.3 (1.5)	12.8 (1.3)	13.1 (1.2)
Parity	0.9 (1.1) ^b	2.0 (0.9)		1.2 (0.4)	
% with a child age 3 years	15.1 ^b	33.8		17.6	
Age at first full-term pregnancy (years)	25.0 (3.8)	24.7 (3.6)		25.4 (3.4)	
Age of youngest child (years)	4.7 (3.0)	4.3 (2.8)		5.6 (3.6)	
Cycle length (days)	28.6 (3.4)	28.1 (3.4)	29.4 (3.4)	28.5 (4.1)	28.1 (3.3)
Mean estradiol (days -7 to +6); (pmol/L)	19.2 (10.0)	19.8 (10.5)	20.4 (9.2)	16.7 (9.0)	18.0 (10.1)
Mean luteal P (days +2 to +10); (pmol/L)	152.4 (80.7)	142.3 (69.1)	180.6 (89.0)	146.3 (95.3)	145.0 (80.5)
% with at least one imputed hormone value	41	39	37	41	45
Lifestyle characteristics					
% who smoke	18.9	27.0	18.6	23.5	11.8
% who consume alcohol	94.6	94.6	93.0	100.0	94.1
% highly physically active	23.2	18.9	30.2	29.4	21.6
% moderately physically active	61.1	66.2	53.5	58.8	60.7
% with history of hormonal contraceptive use	83.8	89.2	88.4	94.1	68.6

^a n for individual variables may differ due to missing data.^b Includes whole cohort (with and without children).

TABLE 2

Multiple linear regression models examining associations among marital status, parity, and ovarian hormones in the EBBA-I study

	Mean log (estradiol) (days -7 to +6)		Mean log (progesterone) (days +2 to +10)	
	<i>n</i>	β (95% CI)	<i>n</i>	β (95% CI)
Whole cohort ^a	185		184	
Married ^b		0.19 (0.02, 0.36)		0.19 (-0.01, 0.39)
Youngest child 3 years old ^c		-0.11 (-0.36, 0.14)		-0.12 (-0.42, 0.17)
Youngest child >3 years old ^c		-0.01 (-0.36, 0.11)		-0.13 (-0.36, 0.11)
Parous women only ^d	92		91	
Married ^b		0.20 (-0.04, 0.53)		0.19 (-0.20, 0.52)
Age youngest		0.02 (-0.01, 0.07)		0.01 (-0.04, 0.06)

^aAdjusted for age, BMI, smoking status, alcohol use, history of hormonal contraceptive use, and physical activity level. Among these covariates, BMI was the only significant predictor of estradiol, and no covariate significantly predicted progesterone levels.

^bReference group: unmarried.

^cReference group: nulliparous.

^dAdjusted for age, BMI, smoking status, and physical activity level.