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Marriage and motherhood are associated with lower testosterone concentrations in women

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ABSTRACT

Testosterone has been hypothesized to modulate the trade-off between mating and parenting effort in males. Indeed, evidence from humans and other pair-bonded species suggests that fathers and men in committed relationships have lower testosterone levels than single men and men with no children. To date, only one published study has examined testosterone in relation to motherhood, finding that mothers of young children have lower testosterone than non-mothers. Here, we examine this question in 195 reproductive-age Norwegian women. Testosterone was measured in morning serum samples taken during the early follicular phase of the menstrual cycle, and marital and maternal status were assessed by questionnaire. Mothers of young children (age $\leq$3) had 14% lower testosterone than childless women and 19% lower testosterone than women who only had children over age 3. Among mothers, age of the youngest child strongly predicted testosterone levels. There was a trend towards lower testosterone among married women compared to unmarried women. All analyses controlled for body mass index (BMI), age, type of testosterone assay, and time of serum sample collection. This is the first study to look at testosterone concentrations in relation to marriage and motherhood in Western women, and it suggests that testosterone may differ with marital and maternal status in women, providing further corroboration of previous findings in both sexes.

Introduction

In males, testosterone plays a key role in modulating both mating effort and paternal investment. Physiologically, testosterone facilitates reproductive effort by promoting spermatogenesis and supporting the development of sexually dimorphic traits such as upper body muscle mass and increased stature (Bribiescas, 2001). Testosterone also contributes to reproductive effort behaviorally by promoting male–male competition and mate-seeking behaviors (Archer, 2006). The “challenge hypothesis”, which emerged from avian research, posits that in species with biparental care, testosterone levels rise in contexts of male–male competition (particularly related to mating) and then decrease to facilitate care of young, dependent offspring (De Ridder et al., 2000; Nunes et al., 2000; Peters et al., 2002; Reburn and Wynne-Edwards, 1999; Wingfield et al., 1990; Ziegler, 2000). In humans, cross-sectional data suggests that testosterone levels are higher in: (1) unmarried men versus married men (Booth and Dabbs, 1993; Gray et al., 2002; Kuzawa et al., 2009); (2) uncommitted single men versus single men in committed relationships (Burnham et al., 2003; McIntyre et al., 2006; Sakaguchi et al., 2006; van Anders and Watson, 2006); and (3) non-fathers versus fathers (Gray et al., 2006b; Kuzawa et al., 2009; Muller et al., 2009). Longitudinal work supports this hypothesis as well. One cohort study found that testosterone levels were highest prior to marriage, declined during marriage, and then rose again if divorce occurred (Mazur and Michalek, 1998). Similarly, among single men without children, those who partnered and became fathers during a 4.5 year follow-up period had greater testosterone declines than those who remained single and childless (Gettler et al., 2011a).

Despite great interest in testosterone, marriage, and fatherhood in males, virtually no research has investigated this question in females and the role of testosterone in modulating female mating effort and maternal behaviors is poorly understood. Although testosterone clearly plays a critical role in some components of female mating behavior, such as libido (Braunstein et al., 2005; van Anders et al., 2007), its contribution to other aspects of female mating and parenting effort

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are less apparent. Traditional evolutionary theory holds that intra-sexual mating competition is weak in human females and thus if testosterone primarily modulates intra-sexual mating competition, there should be little association with mating and maternal behavior (Bateman, 1948; Trivers, 1972). Nevertheless, research suggests that testosterone may be associated with mating behaviors in females of some species. In numerous avian species, female testosterone levels vary across the breeding cycle, typically peaking during ovulation and/or prior to the egg laying period, concurrent with the acquisition of mates and territory (Cristol and Johnsen, 1994; Gill et al., 2007; Ketterson et al., 2005; Osorno et al., 2010). In humans, several studies have found positive associations between testosterone and female aggression or competition, however, it is unclear whether these findings are relevant within a mating context (Edwards and Kurlander, 2010; Harris et al., 1996). In fact, the limited research on female testosterone levels and mating status to date has been inconsistent. While some studies have found that among heterosexual women, being in a committed, monogamous relationship is associated with lower testosterone concentrations (Edelstein et al., 2011; van Anders and Watson, 2006), others have failed to find a relationship (Hooper et al., 2011).

Similarly, the research on testosterone and motherhood is in its infancy. Although there is some evidence that in marmosets, elevated testosterone is associated with decreased care-giving among mothers (Fite et al., 2005), to our knowledge, only one published study has examined testosterone, pair-bonding, and motherhood in humans (Kuzawa et al., 2010). In a cohort of Filipino women, waking salivary testosterone levels were lower in pair-bonded versus single women, and in mothers versus non-mothers. Mothers of young children, moreover, had significantly lower testosterone levels than mothers of older children, and only motherhood remained a significant predictor of testosterone levels in multiple regression models. While the results are suggestive, the sample size (n = 67) was small and population demographics skewed heavily towards very young mothers and included few married women without children. Furthermore, the study included women who were breast-feeding and/or using hormonal contraception, and testosterone levels were assayed from sample taken at different points in the menstrual cycle. Given these limitations, we attempted to replicate their study using stricter inclusion criteria in a second, demographically different population.

To this end, we used data from a Norwegian cohort study to test the following primary predictions: (1) testosterone levels are lower in married women than unmarried women; and (2) testosterone levels are lower in women with at least one child under age 3 than in women who do not have a child under 3 (i.e. are either nulliparous or have only older children). Among the mothers, furthermore, we predicted that the age of the youngest child and total parity would both be negatively associated with testosterone levels.

Materials and methods

Study population

206 women participated in the Energy Balance and Breast Cancer Aspects (EBBA-I) study, based in Tromsø, Norway from 2000 to 2002. Participants were aged 25–35 with self-described regular menstrual cycles and no use of hormonal contraceptives within the past six months. Women who had been pregnant or had breast-fed within the previous six months were excluded from participating in EBBA-I, as were women with known histories of infertility, gynecological disorders, or chronic illness. Women participated for one menstrual cycle and received 1000 Norwegian kroner (approximately $160 USD) on average to cover expenses associated with participation. Human subject approvals were obtained from Institutional Review Boards at all participating institutions. The study subjects and protocol have been previously described in greater detail (Furberg et al., 2005). For the current primary analyses, any woman who had complete data on testosterone level, marital status, motherhood, age, height, and weight was included in the analysis (n = 195). The 11 excluded women lacked serum data (n = 6), questionnaire data (n = 5), or both (n = 2). Only mothers were included in secondary analyses (n = 84).

Testosterone concentrations

Fasting morning serum samples were collected during the early follicular phase (days 1–2) of the menstrual cycle and sample collection time was recorded to control for diurnal variation (Table 1). Fresh serum was allowed to rest for an hour after which it was centrifuged and immediately assayed at the University of Northern Norway (UNN) Department of Clinical Chemistry laboratory. Samples collected

Table 1
Characteristics of the study population (mean ± S.D.).

Variable	Non-mothers (n = 111)	Mothers with a child aged 3 or under (n = 31)	Mothers with no child aged 3 or under (n = 53)	p-Value[1]
Anthropometrics				
Age (years)	29.9 ± 3.0	31.9 ± 2.4	32.5 ± 2.5	<0.001[2]
Height (cm)	166.9 ± 6.6	168.3 ± 7.1	166.4 ± 6.0	0.44
Weight (kg)	66.8 ± 11.2	69.8 ± 11.2	69.8 ± 12.6	0.21
BMI (kg/m^2)	23.9 ± 3.6	24.6 ± 3.5	25.1 ± 4.0	0.15
Reproductive measures				
Age at menarche (years)	13.2 ± 1.3	13.3 ± 1.2	12.8 ± 1.5	0.19
Parity	–	1.7 ± 0.6	1.9 ± 0.9	0.38[3]
% married	48%	84%	89%	<0.001[2]
Serum testosterone concentration (nmol/L)	1.5 ± 0.5	1.2 ± 0.4	1.5 ± 0.5	0.006[4]
Time of sample collection (hours since midnight)	9.1 ± 1.1	9.0 ± 0.9	9.1 ± 0.9	0.92
Energetic variables				
Average daily energy intake (kJ)	8.11 ± 0.18	8.70 ± 1.96	7.79 ± 1.92	0.10[5]
Average activity level (scale of 1–3)	2.2 ± 0.8	2.0 ± 0.4	2.1 ± 0.7	0.57
Average hours of sleep per night	8.0 ± 1.1	7.2 ± 0.7	7.6 ± 0.9	0.0003[6]

[1] Significance level for differences across groups based on univariate ANOVAs, unless otherwise noted. Pair-wise differences as noted below.
[2] Non-mothers differed significantly from mothers of children aged ≤3 and mothers of children aged >3.
[3] p-Value based on two-sided, unpaired-*t*-test.
[4] Mothers with a child aged ≤3 differed significantly from non-mothers and mothers with no child aged ≤3.
[5] Mothers of children aged ≤3 differed significantly from mothers of children aged >3.
[6] Non-mothers differed significantly from mothers of children aged ≤3.