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Marriage and fatherhood are associated with lower testosterone in males

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Abstract

In order to study the hormonal correlates of the tradeoff between mating and parenting effort in human males, we examined the salivary testosterone (T) levels of 58 Boston-area men who were either unmarried ($n = 29$), married without children ($n = 14$), or married with children ($n = 15$). Additionally, we asked participants to complete a questionnaire that surveyed their demographic, marital, and parenting backgrounds. We tested the hypotheses that (1) T levels will be lower in married than in unmarried men and (2) married men with children will have lower T levels than unmarried men and married men without children. We also tested a series of hypotheses relating variation in parenting and spousal relationships to T. We found that married men with and without children had significantly lower evening T than unmarried men. No significant differences in T were found among the groups in morning samples. Among married men without children, higher scores on a "spousal investment" measure and more hours spent with a man's wife on his last day off work were both associated with lower T levels. We suggest that lower T levels during the day among fathers may facilitate paternal care in humans by decreasing the likelihood that a father will engage in competitive and/or mating behavior. © 2002 Elsevier Science Inc. All rights reserved.

Keywords: Testosterone; Marriage; Fatherhood; Paternal care; Mating effort; Parenting effort; Challenge hypothesis

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1. Introduction

One of the fundamental features of human male life histories involves the tradeoff between the time and energy that individuals allocate to male–male competition and mate attraction (mating effort) and the time and energy they allocate to caring for their mates and offspring (parenting effort) (Lancaster & Kaplan, 1992). In humans, the existence of this tradeoff may account, in part, for the variation in male mating and parenting effort found across (e.g., Flinn & Low, 1986; Hewlett, 1992; Marlowe, 2000) and within (Chisholm, 1999; Draper & Harpending, 1982) societies and across an individual's life span (Daly & Wilson, 1988).

Research on nonhuman taxa has pointed to the steroid hormone testosterone (T) as a key physiological mechanism underlying the mating/parenting tradeoff in males. Wingfield, Hegner, Dufty, and Ball's (1990) "challenge hypothesis" suggests that T facilitates male–male competition in reproductive contexts and conversely is down-regulated during parental care. Evidence supporting the challenge hypothesis stems from work on monogamous bird species, which show high male T levels during mate procurement and then lowered T levels after males pair with their mates and begin caring for their young (Wingfield et al., 1990). Male T levels remain constant throughout the breeding season in polygynous bird species, coinciding with a lack of male parental effort (Wingfield et al., 1990). Similarly, studies with other species have found that T levels are positively associated with behaviors characterized as mating effort (Creel, Creel, Mills, & Monfort, 1997) and negatively associated with those indicative of parenting effort (Ball, 1991; Wynne-Edwards, 2001; Ziegler, 2000). Experimental manipulations have demonstrated a causal role of T, whereby elevations in T are associated with increased mating effort and reduced parenting effort (Ketterson & Nolan, 1999).

In contrast to the endocrine data from other species, surprisingly little is known about the hormonal correlates associated with the tradeoff between mating and parenting effort in human males. Although no study to date has explicitly tested the challenge hypothesis in humans, there are several existing studies that support the view that T may mediate mating and parenting behavior. In their study of over 4000 servicemen, Booth and Dabbs (1993) found that those with higher T were less likely to have ever married and, if they did marry, they were more likely to have engaged in extramarital sex. Mazur and Michalek (1998) reported that in their sample of married men, T levels were highest around 8 and 4 years prior to marriage and began to decline shortly after marriage. They also showed that men who divorced their spouses experienced elevated T around the time of relationship dissolution. Neither of these studies, however, reported the parental status of their married participants, thereby precluding any analysis of the relationship between T and a tradeoff between male mating and parenting effort. Two recent studies have investigated hormonal changes in expectant and new fathers. Storey, Walsh, Quinton, and Wynne-Edwards (2000) found 33% lower T levels among men whose wives had given birth within the previous 3 weeks compared with men whose wives were due to give birth in 3 weeks or less. They also found that parenting stimuli, such as holding a baby doll, decreased T in these men. Similarly, Berg and Wynne-Edwards (2001) reported that salivary T levels were lower for men expecting the birth of their first child than for controls.

Here we present new data, which address the hypothesis that, as in other species, T is associated with a mating/parenting tradeoff in human males. We predicted that: (1) T levels would be lower in married men than in unmarried men and (2) T levels would be lowest in men with children. We also predicted that (3) marriage duration and a measure of male spousal investment would be negatively correlated with T levels among married men without children because marriage duration and higher levels of spousal investment may correspond with lower mating effort. Furthermore, we predicted that (4) the age of a male's youngest child would be positively correlated with T levels, and a measure of male parental investment would be negatively correlated with T levels. These last expectations arise because more invested fathers, as well as fathers of younger children, may provide higher levels of paternal care.

2. Methods

Fifty-eight Boston-area men voluntarily participated in this study (unmarried men, $n=29$; married men without children, $n=14$; married men with children, $n=15$). Of these men, 48 were graduate, professional, or postdoctoral students affiliated with Harvard University. The men ranged in age from 20 to 41 years (mean age = 29.6 years). Unmarried participants were not involved in committed relationships (defined as a relationship with the same partner lasting longer than 3 months). All married subjects were in first marriages, and all fathers in the study had biological children between 1 week and 4 years of age. Four fathers had more than one child.

To test our predictions, we administered a questionnaire that surveyed the demographic, marital, and parenting backgrounds of participants. The questionnaire also contained a stress inventory (Cohen, Tamarck, & Mermelstein, 1983). Items adapted from Lund (1985) were used to generate a composite "spousal investment" measure, and results of five items were compiled to yield a "male parenting effort" measure (see Table 1). Amount of time spent with spouse on a subject's last day off work was converted to a scale of 1 to 5. Self-reported weekly amounts of exercise were placed on a scale of 1 to 5, and heights and weights were used to determine body mass index (BMI). We included these additional variables because they can be associated with variation in T levels (Campbell & Leslie, 1995; Vermeulen, Goemaere, & Kaufman, 1999).

Additionally, we asked participants to collect four saliva samples (two a.m. samples and two p.m. samples). Samples were collected by the subjects at home, following previously validated protocols (Lipson & Ellison, 1989). Saliva was collected using sugarless chewing gum (to stimulate saliva production) into polystyrene tubes pretreated with sodium azide (a preservative), and was stored by the subjects at ambient temperature until all four samples were obtained. Samples were frozen at $-20\ ^{\circ}C$ until they were assayed. Only morning samples collected between 0600 and 1100 and evening samples collected between 1700 and 2400 were included in the analysis. Participants were instructed to refrain from eating, drinking, smoking, and sexual activity before collecting saliva samples.

Table 1
Items used to generate "spousal investment" and "male parenting" effort scales

	Spousal investment scale (items adapted from Lund, 1985)
1	Spending your free time with your partner rather than doing things or seeing other people.
2	Spending continuous time along together such as evenings together, weekend outings, or vacations.
3	Buying gifts for your partner.
4	Sharing important personal feelings, problems, and beliefs with your partner.
5	Revealing your sexual preferences with your partner.
6	Exploring sexual activities with your partner.
7	Sharing income and expenses with your partner, such as having a joint bank account and debts.
8	Contributing financially to your partner or your relationship in general.
9	Trying to develop interests and activities in common with your partner.
10	Making plans for the future such as discussing having children.
11	Telling your partner your true feelings about the relationship such as that you love her.
12	Letting friends know your feelings and plans about your relationship.
13	Integrating your partner into your family.
14	Putting effort into seeing your partner (such as travelling long distances or travelling often).
15	Doing favors for or helping your partner (such as lending money or doing errands).
16	Changing things about yourself to please your partner such as habits, attitudes, or appearance.
17	Restricting your relationships with other potential partners such as being sexually faithful.
18	Changing your career plans or other interests to continue your marriage.
19	Putting effort into 'making the marriage work' when there were problems.
20	Trying to encourage and support your partner.
21	Investing emotionally in your partner in general.
Scoring system	Each of the 21 items scored on a scale from 1 (*extremely small investment*) to 7 (*extremely large investment*), with the total score (possible range = 21 – 147) determined by adding positive scores of all items.
	"Male parenting effort" scale
1	During your last day off, approximately what percentage of the direct childcare (e.g., bathing, feeding, changing diapers, dressing, etc.) did you do?
2	During your last day off, approximately what percentage of your waking hours was spent doing these direct child care activities?
3	During a normal working day, approximately what percentage of your waking hours is spent doing these direct child care activities?
4	During your last day off, approximately what percentage of your waking hours was spent engaged in "playtime" activities (i.e., reading books, playing with toys, watching cartoons, etc.) with your child(ren)?
5	During a normal working day, approximately what percentage of your waking hours is spent engaged in "playtime" activities (i.e., reading books, playing with toys, watching cartoons, etc.) with your child(ren)?
Scoring system	Answers given in intervals (e.g., 0–20%, 20–40%, etc.) in which the first interval (0–20%) scored as 1, the second (20–40%) as 2, and so forth, meaning that possible overall scores could range between 5 and 25.

T levels in the saliva were measured by radioimmunoassay according to published protocols (Ellison, Lipson, & Meredith, 1989) in Harvard's Reproductive Ecology Laboratory.

After centrifugation, 1 ml of each sample was extracted twice in diethyl ether, and the extracted samples were run in assays using a specific antiserum (anti-T #250 supplied by G.D. Niswender, Colorado State University) and a four-position tritiated T competitor (Amersham). Assay sensitivity, the smallest amount of steroid distinguishable from zero with 95% confidence, averaged 16.2 pmol/l; T levels in the samples ranged from 37 to 1153 pmol/l. Interassay variability, estimated from high and low pools, was 10.0% for the high pool and 19.5% for the low pool, and intra-assay coefficients of variation averaged 8.1%. All samples from an individual were run in the same assay, and each assay included samples from unmarried men and married men with and without children. A mean a.m. and p.m. T value was calculated for each subject by averaging his two morning and two evening samples, respectively.

We used analysis of variance (ANOVA) for three-group comparisons. Student's *t* tests (paired and unpaired) and regression analyses were also employed where appropriate. All statistical tests were one-tailed because we predicted differences in specified directions.

3. Results

All T values fell within the normal range of values reported in other studies (Read, 1993), and T levels were lower in evening than in morning samples for all participants (paired *t* test; $t=11.90$, $df=56$, $P<.0001$), which is consistent with the circadian pattern of T secretion (Dabbs, 1990).

Since in our study (a.m. samples: $y=756.8-7.7x$, $r^2=.05$, $P=.10$; p.m. samples: $y=536.3-8.2x$, $r^2=.15$, $P=.003$) and in previous studies (e.g., Dabbs, 1990), male T levels decline with age, we had to control for age effects before we could investigate the

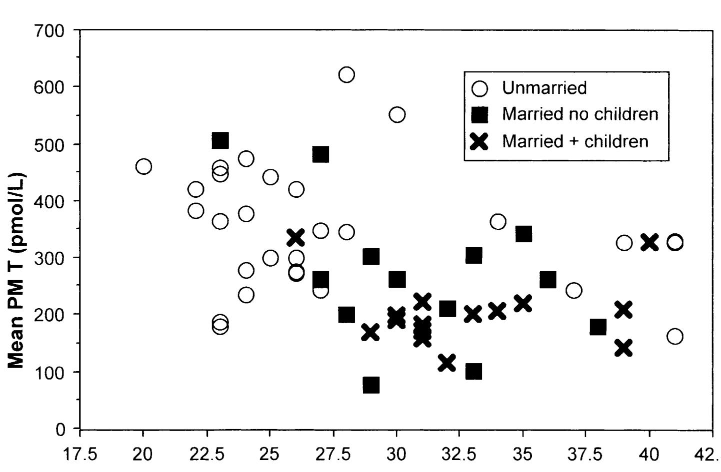

Fig. 1. Individual mean evening T levels plotted against age.

relationship between T and male mating and parenting status (see Fig. 1). We used the residuals of a linear regression of age on T to compare the status groups. These data supported our first prediction since after controlling for age, married men without children had significantly lower T levels than unmarried men (see Fig. 2 and Table 2). However, this difference was only true for evening samples (unpaired *t* test, a.m.: $t=1.18$, $df=41$, $P=.122$; p.m.: $t=1.41$, $df=41$, $P=.045$). Our second prediction was also partially supported by the data since T levels for fathers were significantly lower than T levels for unmarried men (unpaired *t* test, $t=3.45$, $df=42$, $P=.0005$) but were not significantly lower than levels for married men without children (unpaired *t* test, $t=1.30$, $df=27$, $P=.103$). Again, this difference was apparent only in evening samples (ANOVA, a.m.: $F=0.90$, $df=2$, $P=.413$; p.m.: $F=5.43$, $df=2$, $P=.001$; Fig. 2). Also, we found no significant difference among the groups in the mean change in T (mean a.m. – mean p.m.) over the course of the day after controlling for the effects of age (ANOVA: $F=0.693$, $df=2$, $P=.505$). To also control for other possible confounding factors that we derived from the T literature — BMI, exercise, stress — we entered age and relationship into a stepwise multiple regression model with these other variables. This analysis revealed that relationship status was the only significant predictor of evening T levels in our sample (relationship status: $\beta=-.521$, $P<.0005$; age: $\beta=-.228$, $P=.091$; BMI: $\beta=.021$, $P=.877$; exercise: $\beta=.089$, $P=.514$; stress: $\beta=.112$, $P=.412$).

Because the association between relationship status and T only held for evening samples, we tested Predictions 3 and 4 using only these values. Contrary to our predictions, we found that duration of marriage ($r_s=-.139$, $n=14$, $P=.317$) and our composite measure of "male parenting effort" ($r_s=.125$, $n=15$, $P=.328$) did not negatively correlate with evening T levels. Nor was age of youngest child positively correlated with evening T ($r_s=-.146$, $n=15$, $P=.302$). However, "spousal investment" scores and the amount of time participants spent with their spouses on their last day off work did negatively correlate with evening

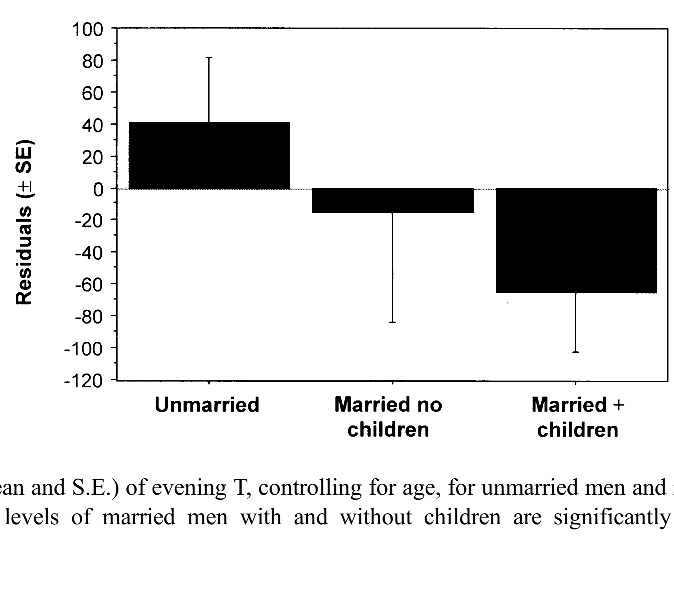

Fig. 2. Residuals (mean and S.E.) of evening T, controlling for age, for unmarried men and married men with and without children. T levels of married men with and without children are significantly lower than those of unmarried men.

Table 2
Mean (S.E.) a.m. and p.m. T levels (pmol/l) according to relationship status

	Unmarried men	Married without children	Fathers
n	29	14	15
Mean a.m. T (S.E.)	578.6 (40.2)	478.6 (55.5)	477.5 (33.1)
Mean p.m. T (S.E.)	350.2 (20.3)	267.7 (32.5)	203.5 (15.4)

T levels among married men without children (spousal investment: $r_s = -.515$, $n = 14$, $P = .030$; time spent with spouse: $r_s = -.645$, $n = 14$, $P = .006$).

4. Discussion

Controlling for age, we found that married men without children had lower evening T levels than unmarried men. Though fathers did not have significantly lower evening T levels than married men without children, fathers had markedly lower T levels compared with unmarried men. These results support the view that T mediates a tradeoff between mating and parenting effort in human males, as suggested by Wingfield et al.'s "challenge hypothesis." While unmarried men (higher T) invest only in mating effort, fathers (lower T) also invest in parenting effort, while presumably decreasing investment in mating effort.

The results also provide some support for our predictions relating T levels to variation in male spousal relationships and parenting. For two measures (a "spousal investment" score and reports of time participants spent with their spouses on their last day off work), our findings support the view that greater spousal investment corresponds with lower evening T levels. Our other predictions regarding the relationship between parenting effort and T were not supported by the data.

Our finding that evening, but not morning, male T levels are consistent with the predicted effects of relationship and parental status suggests that daily interactions, thoughts, and emotions may have modulating effects on male T. In keeping with this view, so-called "winner/loser" effects (in which T levels rise in competitors prior to a match, and remain higher in winners afterwards) show that short-term events can affect T levels (Mazur & Booth, 1998). Thus, we expected fathers to experience greater decreases in T across the day than unmarried men (controlling for age). Fathers did exhibit greater decreases across the day, but this difference was not significant (*t* test, unequal variance, $df = 40$, $P = .134$). The moderate sample size, and resulting low statistical power, might underlie this result. Certainly, this interpretation is in agreement with previous studies that have shown that hormonal signatures of social interactions are most evident in evening, rather than morning samples. For example, Muller and Wrangham (2001) found significant correlations between male chimpanzee urinary T and dominance rank in p.m., but not a.m. samples. Similarly, in their investigation of !Kung men, Worthman and Konner (1987) observed significant differences in T levels in p.m., but not a.m., serum samples when they compared levels on days when men hunted with levels on days when they did not hunt. Finally, the Berg and Wynne-Edwards (2001) study of expectant fathers observed significantly lower T levels compared with controls in p.m. but not a.m. samples.

Our work does not examine whether changes in T represent a cause or effect of behavior. We nonetheless propose a reciprocal model of T and mating and parenting behavior. Since it appears that T levels play a facilitatory role in competitive interactions among males (see Mazur & Booth, 1998), relationship stimuli (interacting with or thinking about a mate; interacting with or thinking about one's small child) that down-regulate male T levels during waking hours may alter the likelihood of individuals engaging in certain behaviors. In Wingfield et al.'s (1990) model, these lowered T levels translate into reduced mating effort. Alternatively, they may have the more direct benefit of facilitating direct paternal care (as suggested by the results in Storey et al., 2000). Engaging in mating and parenting behaviors might themselves then alter T levels, continuing this feedback process.

Much remains for future research in this area. Manipulations of physiological T levels in human males could examine the effects of T on attention to relevant social stimuli (e.g., an infant cry or threatening face: see Pope, Kouri, & Hudson, 2000). Cross-cultural study could examine variation in male T levels within societies in which males engage in different amounts of mating and parenting effort than our U.S. setting. An important implication of this research is the suggestion that variation in T may constitute part of the neuroendocrine basis of human paternal care.

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