Fatherhood, pairbonding and testosterone in the Philippines

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ABSTRACT

In species with a high level of paternal care, including humans, testosterone (T) is believed to help mediate the trade-off between parenting and mating effort. This hypothesis is supported by the observation of lower T in pairbonded men or fathers compared to single, non-fathers; however, prior work has highlighted population variation in the association between T and pairbonding or fatherhood status. Here we evaluate this hypothesis in a large ($n = 890$), representative birth cohort of young men (age range 20.5–22.5 years) living in Cebu City, the Philippines. Bioavailable T was measured in saliva collected prior to bed and immediately upon waking the following morning. Plasma T and luteinizing hormone (LH) were measured in morning plasma samples. In this sample, 20% of men were pairbonded, defined as living with a partner or married, 13% were fathers, and roughly half of fathers reported involvement in childcare. Pairbonded men had significantly lower T at both times of day. Unlike in other populations, this relationship was accounted for entirely by fatherhood status: among the large sub-sample of non-fathers, mean T was nearly identical among pairbonded and single men. There was a strong association between self-reported involvement in childcare and lower evening T, supporting the idea that the evening nadir in T is related to social interactions across the day. Similar relationships were found for total plasma T and LH, suggesting that these relationships are coordinated by centrally-mediated changes in LH secretion. The relatively modest T difference in relation to fatherhood at Cebu, in comparison to other studies, may reflect a lower level of paternal involvement in childcare activities in this population. Our findings using a large, well-characterized birth cohort support the hypothesized role of T as a mediator of mating and parenting effort in humans, while contributing evidence for cultural variation in the relative importance of pairbonding and fathering to these relationships.

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Introduction

Current models of human male reproductive ecology emphasize the importance of testosterone (T) as a modulator of physiological and behavioral components of reproductive effort (Bribiescas, 2001; Ellison, 2003). In addition to its organizational effects on male reproductive development, testosterone supports spermatogenesis and exerts anabolic effects on somatic tissues, leading to sexually dimorphic traits, such as increased stature and strength, that contribute to competitive ability and sexual attractiveness (Bribiescas, 2001; Ellison, 2001, 2003). T also promotes libido (Isidori et al., 2005) and moderates responses to social challenges (Archer, 2006; Hermans et al., 2008; van Honk et al., 1999, 2000).

The behavioral effects of T are interpreted as expressions of male mating effort, which may compete with effective paternal care in species in which males are involved in care of dependent offspring (Wingfield et al., 1990; Gray 2003). Data from a range of vertebrates

support the idea that modifying T concentration is one strategy that allows males to mediate this trade-off between mating effort and parenting effort. Evidence for this is particularly clear in birds, as studies of more than 60 species are consistent with tenets of the 'challenge hypothesis,' which suggests that T levels increase when males compete for territory and mates and decrease when males must care for offspring (Goymann et al., 2007; Hirschenhauser et al., 2003; Wingfield et al., 1990). Although paternal care is less common in mammals, the males of some species with biparental care exhibit a decrease in T in the presence of dependent offspring (reviewed in Wynne-Edwards, 2001). Tests of this hypothesis in humans, however, have produced mixed results. In populations investigated to date, pairbonded men (Booth and Dabbs, 1993; Burnham et al., 2003; Gray et al., 2002, 2004a, 2007a; Mazur and Michalek, 1998; McIntyre et al., 2006; Sakaguchi et al., 2006; van Anders and Watson, 2006a) have been found to maintain lower T levels than their single counterparts in some, but not all populations (Flinn et al., 1998; Gray, 2003). In studies to date, fathers have been shown to exhibit reduced T compared to married and single men in some (Gray et al., 2006; Muller et al., 2009), but not all cultures (Gray et al., 2002, 2004a) in which non-trivial levels of paternal care are common. Similarly,

studies tracking men's T through a partner's pregnancy have shown that T decreases from the last weeks of the mother's pregnancy to the first weeks post-partum (Berg and Wynne-Edwards, 2002; Storey et al., 2000), while fathers exposed to infant cries exhibit greater acute spikes in T than those exposed to control stimuli (Fleming et al., 2002; Storey et al., 2000).

If T functions to modulate mating and parenting effort in humans, it is important to identify whether pairbonding, interaction with offspring, or both are important determinants of HPG (hypothalamic–pituitary–gonadal) activity (Archer, 2006; van Anders and Watson, 2006b). Significant changes in T associated with fatherhood have not been consistently found (Burnham et al., 2003; Gray, 2003; Gray et al., 2002, 2004a, 2006, 2007b). It is thus presently difficult to conclude whether paternity and investment in offspring are associated with a greater reduction in circulating T than pairbonding alone. Such effects may be contingent on individually variable and culturally-bound characteristics like the level of paternal care (Gray and Campbell, 2009). In support of this notion, Muller et al. (2009) recently reported that fathers in a foraging population, among whom rates of direct paternal care are high, had substantially lower T levels than non-fathers, while no such difference existed in a pastoralist group in which men provide little or no direct childcare.

An additional unknown is the functional importance of circadian dynamics in T production. In men, T levels peak early in the morning, between 04:00 and 08:00, and then decline across the day, reaching a nadir around 24:00 (van Cauter, 1990). A similar pattern is evident in old world monkeys and apes, including the chimpanzee (Muller and Lipson, 2003). A wide range of studies in both humans (Berg and Wynne-Edwards, 2001; Gray et al., 2002, 2004a; Worthman and Konner, 1987) and chimpanzees (Muller and Wrangham, 2004) have reported stronger correlations between T and behavioral measures in afternoon, compared to morning samples. For example, a meta-analysis of 45 independent studies conducted by Book et al. (2001) showed stronger correlations between measures of aggression and afternoon T levels, compared to morning levels. Additionally, in several North American studies, T differences between fathers and non-fathers were either less prominent or non-existent in morning samples (Berg and Wynne-Edwards, 2001; Gray et al., 2004a,b). One interpretation of these findings is that afternoon samples are sensitive to the effects of social interactions through the day (Muller and Wrangham, 2004). In support of this idea, Muller et al. (2009) noted larger diurnal T decreases in Hadza fathers with young children, who provided more intensive care, than in those with older children, who were less involved with childcare. This test involved a sample of only ten fathers, however, so it remains to be seen whether this effect can be replicated in a larger sample.

In this paper, we evaluate the relationship between pairbonding status, fatherhood, childcare and male HPG (hypothalamic–pituitary–gonadal) axis function in a large sample of Filipino males. In the Philippines there is a rapidly growing incidence of consensual unions, and cohabitation without legal marriage (NSO Philippines, 2004; Gultiano et al., in press) such that there is largely no longer a formal distinction between "married" and "cohabitating" except for the legal recognition and religious rituals associated with marriage. This cultural shift suggests that co-residence with a female partner, as opposed to legal marital status, may be the primary romantic commitment of interest for this sample vis-à-vis levels of male T.

Furthermore, as in most cultures (Hewlett, 1992; Lamb, 1987, 2004), Filipino fathers usually spend substantially less time with their children compared to mothers (Medina, 2001). In terms of traditional parenting roles, Filipino fathers have acted primarily as resource providers and disciplinarians while mothers have engaged predominately in childcare (Liwag et al., 1998; Medina, 2001). However, paternal care is an emerging phenomenon, especially among young, more educated and professional men (Tan, 1997; Pelaez-Marfori,

1987), with fathers engaging in activities such as telling stories and reading to children, taking them out for walks, and playing with them (Early Child Development survey, unpublished data). In the Philippines, it is common for extended households in which a pairbonded couple co-reside with their parents and/or other siblings. As a result, individuals providing childcare frequently include other (non-parental) members of the household like grandparents, aunts, and uncles. The availability of non-parental caregivers has been shown to decrease paternal care in other cultural settings (Fouts, 2008; Leonetti et al., 2004). Thus, this cultural residence pattern might affect the potential association between T and fatherhood, particularly if time spent involved in childcare is a significant mediator of such a relationship.

Data for the present analyses come from a large, representative sample of young men (n = 890) from a birth cohort (age 20.5–22.5 years) living in Cebu City, the Philippines. Household rosters and other questionnaire data are used to 1) test the hypothesis that fatherhood, pairbonding status, and involvement in childcare will predict lower T levels in this sample; 2) clarify the functional importance of circadian T dynamics by evaluating the relative strength of these associations with waking and evening T levels; 3) evaluate the possible role of central (e.g. hypothalamic–pituitary) vs. peripheral regulation as mediators of any documented associations as reflected in plasma total T and LH.

Materials and methods

Data come from the Cebu Longitudinal Health and Nutrition Survey (CLHNS), a population-based study that has followed a large birth cohort born in 1983–1984 (Adair et al., 2001; Adair et al., 1993; Kuzawa and Adair, 2003). Participants were interviewed and measured by trained interviewers in home during 2005–2006. Body weight, height, waist circumference, and triceps and subscapular skinfold thicknesses were measured using standard anthropometric techniques (Lohman et al., 1988). The body mass index (BMI) was calculated as the ratio of weight (kg)/height (m^2). Dietary intake was measured using two 24-hour recalls on consecutive days and the mean was used in analyses. Energy intake was calculated using Philippines Food Composition Tables produced by the Food and Nutrition Research Institute of the Philippines (F.N.R.I., 1997). This research was conducted under conditions of informed consent with human subjects clearance from the Institutional Review Boards of Northwestern University and the University of Chapel Hill, North Carolina.

Pairbonding, fatherhood and childcare

As noted above, consensual unions (cohabitation without legal marriage) are increasingly common in the Philippines (NSO Philippines, 2004; Gultiano et al., in press), such that there is no longer a formal distinction between "married" and "cohabitating" except for the legal recognition and religious rituals associated with marriage. Recent surveys and studies (NSO Philippines, 2004; Gultiano et al., in press) have merged marriage and consensual unions into a single category of marital status. Here, men were classified as "pairbonded" if they were currently living with a partner and/or were legally married. We defined a series of variables based upon each man's household roster. Fathers were defined as men who were living with one or more son or daughter. Men were not asked specifically to differentiate biological offspring from step-children. However, the presence of step-children is likely small as the sample is limited to young adults from a population in which separation and divorce are uncommon. We also defined variables noting the presence in the household of one or more nieces, nephews and other non-biological offspring. We scored the presence of a niece, nephew, or other young if they lived in the household and were 5 years of age or younger. Men

were coded as being involved in childcare if they named themselves as one of the individuals who had responsibility for taking care of children in the household.

Biomarker assessments

Plasma total testosterone and luteinizing hormone (LH)

Participants were asked to fast overnight for 12 h, and blood samples were collected in home by medical technicians the following morning using EDTA-coated tubes. Mean time of blood draw was 7 am (range 5:40 am–9:30 am). After separation, samples were frozen and shipped on dry ice to Northwestern University for analysis. Plasma total testosterone was analyzed with a commercially available enzyme immunoassay (Diagnostic Systems Laboratories #DSL-10-4000, Webster, TX), as was plasma LH (Immuno-Biological Laboratories #IB19104, Minneapolis, MN). All samples were assayed in duplicate, and control samples were included with each assay to monitor between-assay variation. For plasma T, the coefficient of variation between assays was 13.3% and 5.8% for low and high controls, respectively. For plasma LH, between-assay variation was 5.7% and 8.0% for low and high controls, respectively. All samples remained frozen at − 70 °C until thawed for analysis.

Salivary testosterone measurement

Each participant was provided with instructions and two tubes for saliva collection. The first sample was collected immediately prior to bed. After collection, they sealed the tube and kept it at room temperature. They were instructed to place the second tube next to their bed and to collect the second sample immediately upon waking the following morning. At each collection time, the participant was asked to record the time of collection. Both tubes were collected later that day by an interviewer, who placed the tubes on ice packs in a cooler. Salivary

testosterone has been shown to be stable at room temperature over longer time periods (Dabbs 1991). They were then transported to a freezer where they were stored at − 70 °C until shipment on dry ice to the Laboratory for Human Biology at Northwestern University, where they were stored at − 70 °C. They were thawed, centrifuged, supernatant separated, and aliquoted into smaller tubes for subsequent analysis of individual analytes. Salivary T concentrations were determined in duplicate using an enzyme immunoassay protocol developed and validated for use with saliva samples (Salimetrics #1-2402, State College, PA). The between-assay coefficients of variation were 5.6% and 6.7% for high and low controls, respectively.

Sample selection

During the 2005 survey, 1008 males of the original cohort of 1633 liveborn males, ages 21.5 years (range 20.8–22.6 years), were located and interviewed. Of these, a final sample of 890 individuals agreed to participate in saliva collection, had sufficient sample for analysis and complete questionnaire data and biomarker assessments. Baseline characteristics (1983) of the final sub-sample of 890 males who were included in the present analyses were compared with those who were in the sample at baseline (singleton, liveborn infants). Those lost to follow-up were slightly lighter at birth ($p<0.06$) and were born to more educated fathers, but there were no significant differences between our sub-sample here and the original baseline cohort in birth length, parity, mother's education, maternal height, or mother's or father's age at baseline.

Statistical analyses

All analyses were performed with version 10 of the Stata Statistical Package (College Station, TX). Because testosterone, adiposity, diet, and income variables were all right-skewed, all were log-transformed

Table 1
Characteristics of sample.

Variable	All ($n=890$)	Not fathers ($n=773$)	Fathers ($n=117$)	p[a]
Testicular function				
Morning T (pg/mL)	191.2 ± 76.4	195.4 ± 77.2	163.0 ± 64.2	0.0001
Evening T (pg/mL)	117.6 ± 52.5	120.6 ± 53.0	97.5 ± 43.9	0.0001
Time AM saliva	6.82 ± 2.02	6.89 ± 2.08	6.53 ± 1.74	–
Time PM saliva	18.89 ± 7.03	18.70 ± 7.33	19.67 ± 5.61	–
Usual wake up time	7.70 ± 2.56	7.84 ± 2.61	7.16 ± 2.27	–
Plasma total T[b] (ng/mL)	7.9 ± 2.8	8.0 ± 2.8	7.0 ± 2.6	0.0001
Plasma LH[b] (mIU/mL)	10.3 ± 4.7	10.6 ± 4.7	8.5 ± 3.8	0.0001
Time of blood draw[b]	7.13 ± 0.63	7.15 ± 0.62	7.03 ± 0.62	0.02
Social context				
Household size (persons)	6.3 ± 2.6	6.5 ± 2.7	6.0 ± 2.9	0.05
Pairbonded	19.8%	8.8%	92.3%	0.0001
Duration of pairbond[c] (months)	18.6 ± 14.8	11.6 ± 11.1	23.0 ± 15.1	0.0001
Living w/ niece or nephew	15.4%	16.6%	7.7%	0.02
Living w/ other young	11.8%	12.9%	4.3%	0.01
Anthropometry and diet				
Age (years)	21.5 ± 0.3	21.5 ± 0.3	21.5 ± 0.3	0.04
Height (cm)	163.1 ± 5.9	163.0 ± 6.0	163.4 ± 5.1	–
Weight (kg)	55.9 ± 9.3	55.9 ± 9.4	55.8 ± 8.3	–
BMI (kg/m^2)	21.0 ± 3.0	21.0 ± 3.1	20.9 ± 2.7	–
Waist–hip-ratio	0.95 ± 0.04	0.95 ± 0.04	0.95 ± 0.04	–
Tricep SF (mm)	10.8 ± 5.4	10.8 ± 5.4	10.4 ± 5.3	–
Energy intake (kcal/day)	2188 ± 923	2175 ± 930	2273 ± 873	–
Socioeconomic factors				
Household income (pesos)	557 ± 797	577 ± 837	420 ± 437	0.0001
Live in own household	8.4%	2.4%	47.9%	0.0001
Currently employed[d]	58.1%	55.7%	74.1%	0.0001
In school now	19.0%	20.6%	6.8%	0.0001
Education (last grade)	10.4 ± 3.8	10.6 ± 3.8	9.4 ± 3.8	0.002
Urbanicity score	41.0 ± 13.4	40.8 ± 13.6	42.0 ± 12.6	–

Mean ± SD unless otherwise noted. Time reported as hours since midnight.
[a] Significance level for difference between fathers and non-fathers from 2-sided t-tests for continuous variables and chi-2 for categorical variables. Only reported for $p<0.05$.
[b] $n=862$.
[c] Limited to 176 pairbonded men ($n=68$ pairbonded non-fathers, 108 pairbonded fathers).
[d] $n=869$.

prior to *t*-tests or regression analysis. Analyses built from simple descriptive assessments that used *t*-tests to test for significant differences in means, followed by bivariate assessments of associations between social variables and T variables, and concluding with multiple regression models that adjusted for time of measurement. To evaluate the independent and combined effects of fatherhood, pairbonding and childcare on T, we interacted combinations of categories (e.g. fatherhood × pairbond) and calculated mean values adjusted for factors included in the model.

Results

Table 1 presents the biological, household and socioeconomic characteristics of the total sample and the sub-samples of fathers and non-fathers. Fathers have significantly lower waking and evening salivary T, plasma T and LH. Most fathers were pairbonded, while few non-fathers were pairbonded. Fathers were significantly less likely to live in the same household with nieces, nephews or other children younger than 5 years of age. There were no differences between fathers and non-fathers in body size, adiposity or energy intake. Less than 3% of non-fathers lived in households headed by themselves (and their partner), while nearly half of fathers lived in their own households. Consistent with this, non-fathers lived in households with higher income. Fathers were also more likely to be employed, had attained a lower educational standing and were less likely to currently be enrolled in school.

We next tested whether fatherhood, pairbonding status, childcare and household compositional variables predicted waking and evening salivary testosterone, while adjusting only for time of saliva collection (Fig. 1). Fatherhood, pairbonding status, and childcare were all strong predictors of salivary testosterone, with associations generally stronger with evening T. Although many of these associations were of similar magnitude, self-reported childcare had an especially strong relationship with evening T, being associated with a highly significant 25% lower T level. In contrast, there were no significant differences in T at either time of day based upon the presence of one or more nephews or other young children in the household, while men living with nieces tended to have higher T at both times, and with the difference significant in the evening sample. There was no difference in waking or evening T on the basis of having a son or daughter (father × gender interaction $p > 0.9$ at both times of day, not shown). When we investigated T among fathers in relation to offspring age,

fathers of infants (<1 year old) had roughly 10 mg/dL lower waking T than fathers of older children (147.0 mg/dL vs. 156.9 mg/dL, respectively) but this difference was not significant ($p < 0.39$). Fathers of infants and older children also had similar evening T (85.7 mg/dL vs. 90.0 mg/dL, respectively, $p < 0.57$).

Because fatherhood, pairbonding and childcare tend to be strongly interrelated in this sample, multiple regression models were used to tease apart their relative importance as predictors of T while adjusting for time of measurement and usual wake time (Table 2). Neither pairbonding nor childcare remained significant as predictors of waking or evening T after adjusting for fatherhood status. We next tested for interactions between fatherhood and pairbonding and fatherhood and self-reported involvement in childcare (Fig. 2). Men without offspring had comparable levels of waking T whether pairbonded or not: the 68 men who were pairbonded but not fathers had mean waking T levels nearly identical to the 705 men who were neither pairbonded nor fathers (Fig. 2a). In contrast, the 9 non-pairbonded fathers tended to have higher T than non-pairbonded non-fathers, although the difference was not statistically significant ($p < 0.4$). Men reporting being involved in childcare had lower T at both times of day and was lowest among fathers reporting involvement in childcare (Fig. 2b).

Differences by pairbonding and fatherhood status were also present for plasma total T and luteinizing hormone (LH), both of which were lower in men who were fathers, pairbonded or involved in childcare (Table 3). In multiple regression models (not shown), only fatherhood status was a significant predictor of total T (both $p < 0.05$) in a model that also included either pairbonding status ($p < 0.115$) or childcare ($p < 0.7$). Only fatherhood ($p < 0.001$) status was a significant predictor of LH in a model also including childcare ($p < 0.35$), while pairbonding status ($p < 0.02$) was significantly and more strongly related to LH than was fatherhood ($p < 0.117$) when they were evaluated jointly.

Discussion

Consistent with prior cross-sectional studies, we find that fathers maintained lower levels of waking and evening T than single men (Burnham et al., 2003; Gray et al., 2002, 2004a,b; McIntyre et al., 2006). Unlike some studies, however, pairbonding status was not related to T levels in men independent of fatherhood. One advantage of our large birth-cohort sample is that none of these relationships
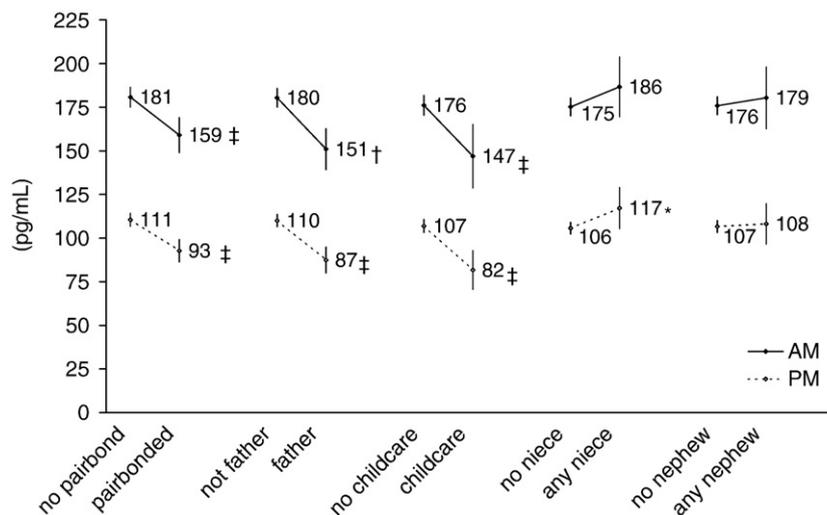

Fig. 1. Geometric mean waking and evening T (+/−95%CI) in men by fatherhood, pairbonding, and childcare and in relation to presence of nieces, nephews and other young children (all limited to 5 years of age or less) living in household. Adjusted for time of saliva collection (waking and evening) and usual wake time (waking). Significance for contrasts by pairbonding, fatherhood, childcare and presence of young * $p < 0.05$, † $p < 0.01$, ‡ $p < 0.001$.

Table 2
Regression models predicting waking and evening salivary T.

	Bivariate[a]	Model 1	p	Model 2[b]	p
Waking T					
Pairbonded	−0.12 (−0.19, −0.06)	−0.04 (−0.14, 0.06)	0.401		
Father	−0.17 (−0.25, −0.09)	−0.14 (−0.25, −0.02)	0.018	−0.13 (−0.23, −0.03)	0.012
Childcare	−0.18 (−0.30, −0.05)			−0.08 (−0.22, 0.07)	0.296
Evening T					
Pairbonded	−0.17 (−0.24, −0.09)	−0.07 (−0.17, 0.04)	0.197		
Father	−0.22 (−0.31, −0.14)	−0.17 (−0.29, −0.04)	0.009	−0.18 (−0.29, −0.07)	0.001
Childcare	−0.26 (−0.39, −0.13)			−0.124 (−0.28, 0.03)	0.118

β(95% CI) of natural log-transformed T adjusted for time of saliva collection (AM and PM) and usual wake time (AM).
[a] Each predictor run in separate model (adjusted for time of collection and wake time). All $p<0.005$.
[b] $n = 705$.

could have been affected by variation in male age, as all subjects were born within a one-year period and all men were within a narrow, 2-year age range when saliva samples were collected. We additionally extend the findings of prior studies in three important ways.

First, we report not only measures of salivary T, which represents the unbound, biologically active fraction of the hormone, but measures of total T and LH. Both total T and LH show similar variation with men's relationship and parenting status to salivary T. This confirms that the mechanism of T reduction is not peripheral reduction in Leydig cell sensitivity or hormone binding by binding globulins, but likely reduced T production secondary to centrally-mediated down-regulation of HPG function.

Second, our data suggest that fatherhood is more strongly related to T production than pairbonding alone among males living in Cebu. Indeed, there was no association between pairbonding and T that was independent of fatherhood and the large sample of non-fathers had similar T levels regardless of their relationship status. A small number of fathers ($n = 9$) were not pairbonded. These individuals had relatively high waking T levels, perhaps suggesting that the combination of fatherhood and pairbonding is necessary to effect T suppression. None of these 9 men reported being involved in childcare, so it is possible that non-pairbonded fathers are simply less invested in paternal effort.

The association between fatherhood and low T production suggests that pairbonded men in this population may not fully transition from a strategy of mating effort to one of parenting effort until they have become fathers. This finding is consistent with data from other non-western populations, in which male mating effort steadily decreases with a couple's fertility. Winking et al. (2007), for example, note that rates of extramarital affairs by both Tsimane men in Bolivia and Ache men in Paraguay (Hill and Hurtado, 1996) are highest early in marriage, rather than later, when women's reproductive value has declined. Among the Tsimane in particular, the rate of extramarital affairs decreases dramatically once men have children, suggesting to Winking et al. (2007) that men reduce mating effort primarily to increase investment in offspring.

Finally, our data support the notion that cultural differences in engagement with offspring can affect T dynamics at the population level (Muller et al., 2009). Although fathers who were actively engaged in childcare exhibited the lowest T levels in this population, the magnitude of the difference between fathers and single men was smaller than in some populations. For example, married fathers in Cebu City maintained 18.3% lower waking levels and 22.3% lower evening levels than single, non-fathers. Among the Tanzanian Hadza, by contrast, these values were 30% and 47%, and in a sample of Boston
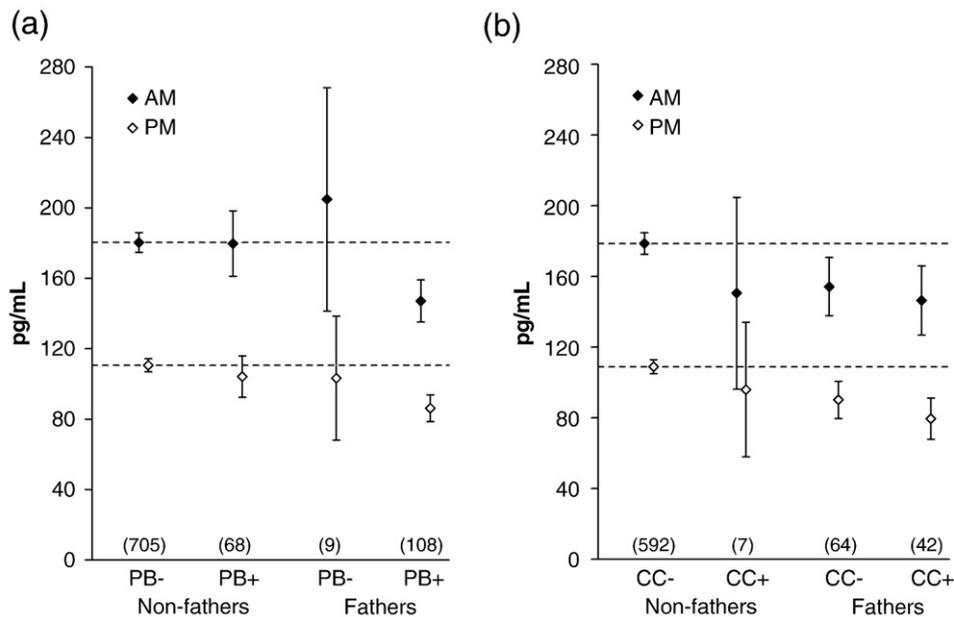

Fig. 2. Geometric mean (+/−95%CI) waking and evening T stratified on fatherhood and (a) pairbonding (PB) status or (b) self-reported involvement in childcare (CC). Adjusted for time of saliva collection (waking and evening) and usual wake time (waking). Numbers in parentheses reflect sample size for that cell. Dashed horizontal lines indicate mean value among (a) non-pairbonded/non-fathers and (b) non-fathers not involved in childcare. Fatherhood × pairbonding interaction $p<0.05$. Contrasts with pairbonded fathers: non-pairbonded non-fathers $p<0.00001$; non-pairbonded fathers $p<0.03$; pairbonded non-fathers $p<0.003$. No other contrasts between groups significant. Fatherhood × childcare interaction not significant ($p<0.6$). Contrasts with non-fathers not involved in childcare: fathers involved in childcare $p<0.003$; fathers not involved in childcare $p<0.010$. No other contrasts between groups significant.

Table 3
Plasma morning LH and total T by fatherhood, pairbonding and childcare.

	T (ng/mL)	LH (mIU/mL)
Not father	7.6 (7.5, 7.8)	9.5 (9.1, 9.8)
Father	6.7 (6.3, 7.1)	7.5 (6.8, 8.2)
Not pairbonded	7.7 (7.5, 7.8)	9.6 (9.2, 10.0)
Pairbonded	6.9 (6.6, 7.2)	7.7 (7.2, 8.3)
No childcare	7.6 (7.4, 7.7)	9.4 (9.1, 9.8)
Childcare	6.7 (6.1, 7.3)	7.4 (6.4, 8.6)

Geometric mean (95% CI) adjusted for time of blood draw; all $p < 0.01$; $n = 862$, childcare $n = 684$.

men, late morning T values were 42% lower among fathers than among non-paired men who were not fathers (Burnham et al., 2003). Although additional ethnographic work will be required to clarify this pattern, it may indicate that men in Cebu who reported relatively higher levels of childcare were not actively engaged with offspring in the way that men in some other populations are (e.g. Muller et al. 2009). Conclusions drawn from this study are limited to Cebu males and may not be applicable to other regions of the Philippines. However, a recent representative survey of populations in several primarily rural regions of the country (the Early Child Development Project) found a level of self-reported childcare comparable to levels reported in this study. For instance, among men in this large survey, only 20% reported participating in childcare activities, including preparing meals for and feeding the child, telling stories and reading to children, taking them out for walks, and playing with them (ECD, unpublished data.). Previous studies have likewise suggested that Filipino fathers engage in meaningful childcare behaviors but at relatively low frequencies compared to mothers (Tan, 1997).

As is true with much of the largely cross-sectional literature on social context and T, our data do not permit us to distinguish the possibility that men with high T are less likely to marry and have children (a trait effect) from the alternative that fathering children has a direct suppressive effect on T (a state effect). Both trait and state effects are possible contributors to the patterns noted here, and both could occur simultaneously. Additional longitudinal studies will be needed to clarify more definitively the nature of the relationship between change in marital and fatherhood status and change in T in this and other populations. In the future, we hope to avail of the longitudinal nature of the study to clarify this question as hundreds more single men in the sample transition to marriage and fatherhood.

In sum, we find evidence for lower testosterone production in fathers in a large sample of Filipino men living in Cebu. Men who were pairbonded also had reduced T, but unlike some other humans populations, this was entirely accounted for by fatherhood status. Involvement in childcare was a strong predictor of T suppression and may contribute to the decline in T associated with fatherhood. There were similar reductions in LH and total T in relation to fatherhood, suggesting that these effects reflect a centrally-mediated decline in testicular T production. Our findings provide additional support for the hypothesis that human males mediate the trade-off between mating and parenting effort by modulating production of T, while highlighting cultural variation in the conditions under which T production is suppressed.

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