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Do testosterone declines during the transition to marriage and fatherhood relate to men's sexual behavior? Evidence from the Philippines

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ABSTRACT

Testosterone (T) is thought to help facilitate trade-offs between mating and parenting in humans. Across diverse cultural settings married men and fathers have lower T than other men and couples' sexual activity often declines during the first years of marriage and after having children. It is unknown whether these behavioral and hormonal changes are related. Here we use longitudinal data from a large study in the Philippines ($n = 433$) to test this model. We show that among unmarried non-fathers at baseline ($n = 153$; age: 21.5 ± 0.3 years) who became newly married new fathers by follow-up (4.5 years later), those who experienced less pronounced longitudinal declines in T reported more frequent intercourse with their partners at follow-up ($p < 0.01$) compared to men with larger declines in T. Controlling for duration of marriage, findings were similar for men transitioning from unmarried to married (without children) ($p < 0.05$). Men who remained unmarried and childless throughout the study period did not show similar T-sexual activity outcomes. Among newly married new fathers, subjects who had frequent intercourse both before and after the transition to married fatherhood had more modest declines in T compared to peers who had less frequent sex ($p < 0.001$). Our findings are generally consistent with theoretical expectations and cross-species empirical observations regarding the role of T in male life history trade-offs, particularly in species with bi-parental care, and add to evidence that T and sexual activity have bidirectional relationships in human males.

Introduction

In the past decade, studies conducted in diverse cultural settings have demonstrated that fathers often have lower testosterone (T) than childless men, especially if they participate in childcare (Alvergne et al., 2009; Gettler et al., 2011a, 2012a; Gray et al., 2006; Muller et al., 2009). Fathers with lower T also express greater need to respond to infant cries (Fleming et al., 2002). Although fathers commonly have lower T than non-fathers, there is evidence that high T men are more successful at securing stable relationships and becoming fathers earlier, after which their T levels decline (Gettler et al., 2011a). Men with elevated T also express more interest in sexual (Edelstein et al., 2011; McIntyre et al., 2006) and romantic (van Anders and Goldey, 2010) opportunities outside their current relationship, and, among US military personnel, higher T men have greater divorce rates (Mazur and Michalek, 1998). These findings are generally consistent with the assumption that elevated T could contribute to competitive, mating-related behaviors that render men less effective in some roles as partners and fathers (Gettler, 2010; Gray and Anderson, 2010; Hirschenhauser and Oliveira, 2006; van Anders, 2013; van Anders et al., 2011; Wingfield et al., 1990). In many non-human species T also facilitates male copulatory behavior and increases libido, which could be an additional pathway through which elevated T might mediate potential mating and parenting trade-offs in human males.

In many mammals, there is a minimal threshold of T necessary for the expression of species-typical male sexual behaviors (Hull and Rodriguez-Manzo, 2009). In both rodents and primates, there is some evidence that once this lower limit is reached, dose-dependent relationships between T (within the normal range) and sexual behaviors are less apparent (Albert et al., 1990; Chambers et al., 1982; Damassa et al., 1977; Michael et al., 1984; Wallen et al., 1991). Findings from human males are broadly consistent with these cross-species patterns. Androgen deficient men often show improvement in sexual libido and frequency of sexual activity after hormonal treatment to normalize their T, but exogenous T has less pronounced effects on reproductively-functional men with T on the low end of normal (Isidori et al., 2005). When healthy men's T production is suppressed, they experience significant declines in sexual desire, which can be restored with

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T administration (Schmidt et al., 2004). However, reproductive-aged males treated with supraphysiological doses of T do not report enhanced sexual activity, with mixed results for increased libido (Anderson et al., 1992; Bhasin et al., 2001; O'Connor et al., 2004).

In line with these findings, research focusing on natural variation in T among reproductive-aged men has not found that higher T males engage in more frequent sexual intercourse compared to individuals with lower T (Brown et al., 1978; Persky et al., 1978; Raboch and Stárka, 1973). Studies examining whether men with elevated T express greater sexual desire have likewise often produced non-significant results (van Anders, 2012). However, in multiple studies, high T men have reported more recent and lifetime sexual partners (Bogaert and Fisher, 1995; Dabbs and Morris, 1990; Pollet et al., 2011).

In light of uncertainties about the role of normal variation in T as an influence on sexual behaviors, it is presently unclear what effect reduced T among new fathers and married men might have on changes in sexual behavior after these life history transitions (Alvergne et al., 2009; Gettler et al., 2011a; Gray et al., 2002, 2006; Mazur and Michalek, 1998; Muller et al., 2009; Perini et al., 2012; van Anders and Goldey, 2010). In multiple cultural settings, rates of intercourse have been shown to decline in the first few years of marriage (Blanc and Rutenberg, 1991) as well as when couples have a young child (Call et al., 1995), with some studies showing pronounced effects during the first-year post-partum (von Sydow, 1999). While specific studies exploring paternal sexuality are rare (Gray and Anderson, 2010), research on Australian, Swedish, and US fathers showed a decline in paternal sexual satisfaction during the first year post-partum and a frequent discrepancy of sexual desire between mothers and fathers during the infancy period (Ahlborg et al., 2005; Condon et al., 2004; Pastore et al., 2007). An additional ~40% of parents stated that childcare responsibilities reduced opportunities for sex (Pastore et al., 2007).

The possible causes or pathways underlying relationships between the parallel decreases in T and sexual frequency during the transition to marriage and parenthood are presently unknown. Although declining T could motivate a reduction in sexual activity (Gray and Anderson, 2010), another possibility is that routine sexual contact affects T production. It is known that sexual intercourse and orgasm acutely increase men's T, with the duration of upregulation ranging from hours to days (Dabbs and Mohammed, 1992; Escasa et al., 2011; Hirschenhauser et al., 2002; Knussmann et al., 1986; Kraemer et al., 1976). Whether reductions in habitual sexual activity, such as that might occur over longer time frames when parents raise young offspring, could decrease basal T production, remains unclear. Finally, both changes could be secondary to some third unmeasured factor, such as increases in psychosocial stress or childcare demands.

The goals of the present analysis are to begin to disentangle these possibilities and to help clarify the relationships between changing behavior and hormones during the transitions into stable relationships and fatherhood. Using longitudinal data collected from a large sample (n = 433) over a 4.5-year period, we test the hypothesis that men who experience more modest declines in T during the transition to marriage and fatherhood will report more frequent sexual intercourse compared to men with larger decreases in T. We evaluate similar models for men who were married fathers at both time points and for subjects reporting a dating (non-married/non-cohabitating) romantic relationship in the year of follow-up. To test for effects of sexual activity on T, we also evaluate whether sexual intercourse frequency prior to marriage and fatherhood predicts the responsiveness of men's T during these life history transitions. Lastly, we test whether elevated T and extra-pair sexual activity are related. To address these hypotheses, we draw on data collected from men participating in the Cebu Longitudinal Health and

Table 1
Sample characteristics stratified by follow-up (2009) marital and fatherhood status.[a]

	All subjects (n = 433)	Non-married childless (n = 152)[b]	Newly married childless (n = 48)[c]	Newly married new fathers (n = 153)[d]	Married fathers (n = 80)[e]	p value
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Demographic characteristics						
Age (years)	25.9 (0.3)	25.9 (0.4)	25.9 (0.3)	26.0 (0.3)	26.0 (0.3)	0.08
Highest grade completed	10.7 (3.3)	11.4 (3.4)	10.7 (3.2)	10.8 (3.0)	9.1 (3.0)	0.0001
Testosterone values						
AM T 2005 (pg/ml)	196.9 (76.0)	197.2 (68.2)	207.4 (109.8)	204.7 (75.3)	175.0 (63.0)	0.03
AM T 2009 (pg/ml)	164.7 (58.9)	175.5 (65.0)	173.3 (54.8)	150.3 (48.5)	166.5 (62.3)	0.001
PM T 2005 (pg/ml)	115.3 (46.1)	116.0 (39.0)	118.8 (50.3)	124.1 (52.6)	95.0 (36.2)	0.0001
PM T 2009 (pg/ml)	90.8 (36.7)	98.1 (36.9)	90.5 (44.7)	83.3 (31.7)	91.7 (37.9)	0.01
Relationship characteristics[f]						
Legally married (%)	42.7	–	31.3	43.8	47.5	0.2
Relationship length (years)	3.6 (2.4)	–	1.6 (1.4)	2.7 (1.3)	6.7 (1.3)	0.0001
Fatherhood characteristics						
Number of children	1.6 (0.9)	–	–	1.3 (0.5)	2.2 (1.0)	0.0001
Age of youngest child (years)	1.9 (1.6)	–	–	1.3 (1.0)	3.1 (1.8)	0.0001
Practice cosleeping (%)[g]	93.6	–	–	94.1	92.5	0.6

[a] Test for significant differences across demographic categories by ANOVA or chi-square.
[b] Non-married and childless (2005 and 2009); in a dating (non-marital/non-cohabitating) romantic relationship in 2009.
[c] Non-married childless (2005); newly married childless (2009).
[d] Non-married childless (2005); newly married new-father (2009).
[e] Married father (2005 and 2009).
[f] Data available only for married/cohabitating individuals (n = 281).
[g] Cosleeping defined as fathers sharing a sleeping surface with children or sleeping in same room as children.

Nutrition Survey, a large, ongoing birth cohort study conducted in the Metropolitan area of Cebu City, Philippines.

Material and methods

Study population

Data were collected in 2005 and 2009 as part of the Cebu Longitudinal Health and Nutrition Survey (CLHNS), a population-based cohort study of mothers and their infants born in 1983–1984 in the Metro Cebu region of the Philippines. Men were an average of 25.9 (± 0.3, SD) years of age at the time of data and sample collection in 2009.

Sociodemographics

Socioeconomic, demographic, and behavioral data were collected during in-home interviews administered by Cebuano-speaking interviewers (Adair et al., 2011) (Table 1). In the present analysis men were classified as "married" if they identified themselves as being legally married or cohabitating (Gettler et al., 2011a; Kuzawa et al., 2009). Unmarried men at baseline were those who reported having never previously been married. Subjects were described as "dating" if they reported a steady romantic relationship that was non-marital and non-cohabitating in the year of follow-up (Gettler et al., 2012b). Fathers were defined as men who reported having one or more biological children (Gettler et al., 2011a). Paternal caregiving was assessed via the question, "How much time do you usually spend providing physical care to your children on a daily basis?" with men grouped by no contact/0 min, less than an hour, 1 to 3 h, and 3+ h (Gettler et al., 2011a). In the present study, only two fathers reported zero care. They were grouped with men reporting less than 1 h of care. Familial cosleeping was defined as fathers sharing a sleeping surface or a room with their children (Gettler et al., 2012a). Self-reported psychosocial stress in the month preceding sample collection was quantified via a modified version of the 10-item Perceived Stress Scale (PSS) (Cohen et al., 1983). Total sleep time was assessed via self-reports.

This research was conducted under conditions of informed consent with human subject clearance from the Institutional Review Boards of the University of North Carolina at Chapel Hill and Northwestern University.

Sexual behavior

During the baseline (2005) interview, men reported their recent sexual activity in response to the question "How often in the past month have you had sex?" using an ordinal scale ranging from "never" to "two or more times per week" (Table 2). Presently, subjects who reported no sex in the prior month or never having had sex were categorized as having no recent sexual activity. Our follow-up (2009) data on frequency of intercourse are restricted to men in committed romantic relationships, as subjects responded to the question, "In the last 12 months, how often have you had sexual intercourse with your steady/spouse/partner?" The ordinal scale ranged from "never" to "five to seven times per week" (Table 3). Also at follow-up, men answered a similar question regarding the frequency with which they had intercourse with someone who was not their current committed partner in the preceding 12 months. To ensure the accuracy of our extra-pair sexual activity variable, we limited the data to subjects who were in a relationship for 12 months or more. Here we grouped subjects according to whether they had engaged in extra-pair intercourse or not in the prior year.

Salivary T collection and measurement

The same saliva collection procedures were used in 2005 and 2009. Each participant was provided with instructions and two polypropylene tubes for saliva collection. The first sample was collected immediately before bed (PM) at mean sampling times of 10:18 PM ± 1:33 (SD) in 2005 and 10:03 PM ± 1:31 (SD) in 2009. The participants were instructed to collect the second sample immediately on waking the following morning (AM) and to report the time of saliva collection. Mean AM sampling times were 6:32 AM ± 1:14 (SD) in 2005 and 6:48 AM ± 1:25 (SD) in 2009. Saliva tubes were collected on the second day by an interviewer and stored at −35 °C until shipment on dry ice to Northwestern University, where they were stored at −80 °C.

Salivary T assessment

T concentrations were determined at the Laboratory for Human Biology Research at Northwestern University using an enzyme immunoassay protocol developed for use with saliva samples (Salimetrics, State College, PA; Kit No. 1-2402). Interassay coefficients of variation were 13.7% and 11.5% for high (200 pg/ml) and low (20 pg/ml) kit-based control samples, respectively, in 2005 samples and 7.8% and 17.9% for high and low control samples, respectively, in 2009 samples.

Statistical analysis

All analyses were conducted using version 12.1 of Stata (Stata Corporation). AM T (pg/ml), PM T (pg/ml), sleep time, PSS, offspring age, and duration of marriage were analyzed as continuous variables. AM and PM T were adjusted for time of sampling and usual wake time (AM samples only) before calculating absolute change in T (ΔT) between baseline (2005) and follow-up (2009) (2009T minus 2005T) (Gettler et al., 2012a). Changes in PSS and sleep time were calculated by subtracting 2005 values from 2009 values.

We first compared subjects, stratified according to their relationship/marital status (follow-up), on a series of socio-economic, demographic, and behavioral variables using ANOVA or chi-squared tests (Table 1). Among unmarried men at baseline, the majority of subjects reported no intercourse (>80%), with very few engaging in frequent intercourse (i.e. at least weekly), in 2005 (Table 2). This limited our ability to examine change in intercourse frequency over the study period, with additional complications due to the differing sexual activity question formats between the two surveys. Consequently, in our main statistical models we assessed whether longitudinal changes in T related to sexual

Table 2
Baseline sexual intercourse frequency (2005), stratified according to marital and fatherhood status over 4.5 year study period.[a,b]

	All subjects (n = 433)	Non-married childless (2005 & 2009) (n = 152)	Non-married childless (2005); newly married childless (2009) (n = 48)	Non-married childless (2005); newly married new father (2009) (n = 153)	Married fathers (2005 & 2009) (n = 80)
Virgin	27.3	34.9	31.3	32.7	0.0
Not in last month	**41.6**	**50.7**	**41.7**	**44.4**	18.8
Once or twice (last month)	13.4	9.9	16.7	7.2	**30.0**
One time per week	7.4	0.7	4.2	7.9	21.3
Two or more times per week	10.4	4.0	6.3	7.9	**30.0**

[a] Values are percentages (%); the most common response in each demographic category is bolded.
[b] Response rates to the question, "How often in the past month have you had sex?"

Table 3
Follow-up sexual intercourse frequency (2009), stratified according to marital and fatherhood status over 4.5 year study period.[a,b]

	All subjects (n = 433)	Non-married childless (2005 & 2009) (n = 152)	Non-married childless (2005); newly married childless (2009) (n = 48)	Non-married childless (2005); newly married new father (2009) (n = 153)	Married fathers (2005 & 2009) (n = 80)
Never	0.5	1.3	0.0	0.0	0.0
Less than monthly	10.2	21.7	0.0	6.5	1.3
Once or twice per month	20.1	**27.0**	16.7	13.7	21.3
More than twice per month but not weekly	13.6	15.1	6.3	16.3	10.0
Once or twice per week	**43.0**	26.3	**47.9**	**49.0**	**60.0**
Three to four times per week	11.1	7.9	27.1	12.4	5.0
Five to seven times per week	1.6	0.7	2.1	2.0	2.5

[a] Values are percentages (%); the most common response in each demographic category is bolded.
[b] Response rates to the question, "In the last 12 months, how often have you had sexual intercourse with your steady/spouse/partner?"

intercourse frequency at follow-up using ANOVA/ANCOVA. Men were grouped based on having sex less than weekly, one or two times per week, and three or more times per week at follow-up. The full range of responses to the sexual intercourse question at follow-up is provided in Table 3. We controlled for covariates that we hypothesized might confound the relationship between T and sexual activity, including duration of marriage (cohabitating/married men), age/number of offspring, and childcare responsibilities (fathers). In addition to testing for relationships between follow-up sexual intercourse activity and absolute longitudinal change in T, we conducted similar models with residualized change in T values (removing the effect of baseline T). These adjustments were conducted by separately regressing change in AM and PM T on their baseline values and then predicting the model's residuals, which removes the effect of the independent variable on the dependent variable.

To test for effects of sexual activity on T, we used ANOVA to predict men's longitudinal decline in T from their baseline sexual intercourse frequency. Finally, we predicted infidelity at follow-up from men's longitudinal change in T and assessed cross-sectional relationships between T and infidelity. In all the analyses below, T values were converted to z-scores before running models to standardize coefficients. Effect sizes (Cohen's *d*) were calculated for select analyses using the user-written "cohend" command in Stata, which accounts for uneven group sizes (Rosnow et al., 2000).

Analyses focusing on married men and fathers were limited to subjects living in the same household with their partners and children. Among men with all behavioral and hormone data, excluded participants included one married non-father who was not residing with his partner and eight married fathers who were living with a partner but not their children. Two subjects with otherwise complete data were excluded because of T values that were 9 SD above the sample mean. Finally, men who had sleeping patterns consistent with shift work, which increases the likelihood of disrupted circadian rhythms for T (Touitou et al., 1990), potentially due to disrupted sleep (Leproult and Van Cauter, 2011), were eliminated from the analysis (2005, n = 31; 2009, n = 25). Here, excluded men with sleep–wake times consistent with shift work had significantly lower 2005 AM T [174.0 ± 53.4 (SD) pg/ml] compared to men keeping regular sleep–wake patterns (196.9 ± 76.6; $p = 0.014$). Results were similar for 2009 AM T: excluded "shift workers," (136.2 ± 57.7); men with regular sleep–wake patterns (164.7 ± 58.9; $p = 0.017$).

Results

Table 1 summarizes the sociodemographic and biological characteristics of the full sample and stratifies the data according to marital and fatherhood status. Married fathers (2005 and 2009) were less well-educated, on average, compared to men in other sociodemographic categories. At follow-up, fathers had generally been married longer than married childless men. As reported previously (Gettler et al., 2012a), familial cosleeping is the norm in this sample. Tables 2 and 3 provide detailed sexual behavioral data from baseline and follow-up. At baseline, married fathers (2005 and 2009) were the only sub-group among whom a majority (51%) reported frequent sexual intercourse (i.e. at least weekly). Also at baseline, substantial percentages of unmarried men reported no sex (>41%) in the month prior to sampling or having never had sex (>31%; Table 2). At follow-up, married men most commonly reported having intercourse one to two times per week (>47%; Table 3).

Using ANCOVA, we first tested whether changes in T (ΔT; z-scored) related to sexual activity at follow-up across the entire sample, controlling for marital and fatherhood status. ΔAM T was not significantly related to sexual activity ($p > 0.1$). There was a significant relationship between ΔPM T and sexual intercourse frequency at follow-up [model: $F(df\ 5, 432) = 8.97$; $R^2 = 0.095$; $p < 0.0001$; sexual activity: $p = 0.001$]. Subjects engaging in sex 1–2 times per week (pairwise comparison, 95% CI: 0.26, 0.06 to 0.47; $p = 0.011$) or 3+ times per week (0.51, 0.21 to 0.80; $p = 0.001$) had milder declines in PM T relative to men having sex less than weekly (Fig. 1). In the model that included sexual activity, newly married non-fathers (both $p < 0.05$) and newly married new fathers (both $p < 0.001$) had greater declines in PM T compared to unmarried childless men and married fathers. Ordered logistic regression analyses that included marital/parenting status revealed that married men were more likely to have frequent sexual intercourse at follow-up than unmarried men [odds ratio (OR), 95% CI:

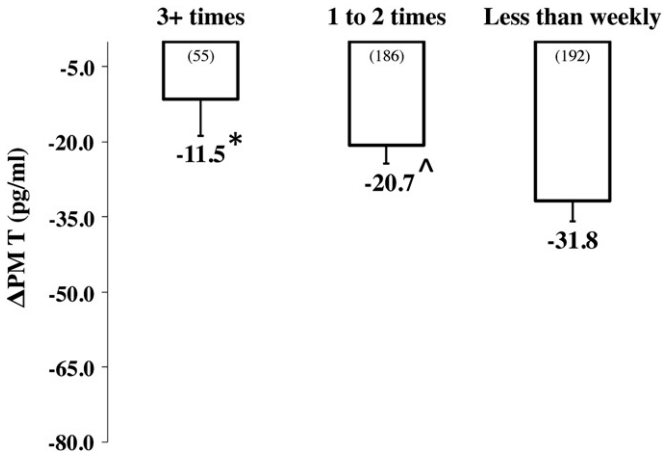

Fig. 1. Changes (Δ) in PM T values (2005 to 2009) based on sexual intercourse frequency at follow-up (less than weekly, 1–2 times per week, 3+ times per week) for the entire sample. Values were adjusted for time of saliva collection. Sample sizes in parentheses at column bases. In a bivariate ANOVA, subjects reporting sex 1–2 times per week (^$p = 0.045$) and 3+ times per week (*$p = 0.013$) differed from those engaging in sex less than weekly. See Results for full model details.

6.72, 3.49–12.94; $p < 0.0001$], and fathers were less likely to report frequent intercourse than non-fathers (OR 0.45, 0.25–0.82; $p = 0.009$).

To ensure our results for absolute ΔT were not heavily influenced by disparities in baseline T, we ran additional models with residualized ΔT (with baseline T influences removed, see Material and methods). Controlling for marital/fatherhood status, we found a borderline relationship between residualized ΔAM T and sexual activity [model: $F(df\ 5, 432) = 4.68$; $R^2 = 0.052$; $p = 0.0004$; sexual activity: $p = 0.053$]. Men reporting sex 3+ times per week had more modest declines in AM T compared to those reporting sex less than weekly (pairwise comparison, 95% CI: 0.36, 0.06 to 0.66; $p = 0.020$) and 1–2 times per week (0.34, 0.04 to 0.64; $p = 0.026$). The relationship between sexual activity and residualized ΔPM T was significant [model: $F(df\ 5, 432) = 4.68$; $R^2 = 0.052$; $p = 0.0004$; sexual activity: $p = 0.029$]. Subjects engaging in sex 3+ times per week showed milder decreases in PM T compared to those reporting sex less than weekly (pairwise comparison, 95% CI: 0.40, 0.10 to 0.71; $p = 0.010$) and 1–2 times per week (0.37, 0.07 to 0.66; $p = 0.017$).

We next evaluated whether ΔT between baseline and follow-up positively related to sexual behavior at follow-up, stratifying according to marital and fatherhood status (see demographic categories in Tables 1–3), as sexual behavior, ΔT, and their covariates are likely to differ across life history stages. Applying ANOVA, we first tested these models among men who were unmarried and childless at baseline but reported dating (non-marital/non-cohabitating), with no offspring, at follow-up ($n = 152$). Men with a milder decline in T over the 4.5-year period did not report more frequent sexual intercourse at follow-up: ΔAM T ($p > 0.5$) and ΔPM T ($p > 0.2$; Fig. 2A). Models for residualized ΔT were also non-significant (both $p > 0.4$).

Focusing on men who transitioned from being unmarried and childless at baseline to being newly married non-fathers ($n = 48$) at follow-up, we evaluated whether subjects with more modest declines in T had more frequent sexual intercourse at follow-up. ΔAM T and ΔPM T were non-significant in bivariate models (both $p > 0.3$). Intercourse frequency has been shown to decrease during the early years of marriage (Udry, 1980) and duration of marriage is related to ΔT in newly married men in this sub-sample (i.e. correlation to ΔPM T: $r = 0.43$, $p = 0.002$), potentially confounding the association between sexual activity and ΔT. After the addition of marriage duration ($p = 0.0002$) to the model, men with a less pronounced decrease in PM T during the transition to marriage reported more frequent intercourse at follow-up [model: $F(df\ 3, 47) = 6.51$; $R^2 = 0.307$; $p = 0.001$; sexual activity: $p = 0.026$]. Newly married non-fathers engaging in sex 1–2 times per week (pairwise comparison, 95% CI: 0.83, 0.17 to 1.48; $p = 0.015$) or 3+ times per week (0.93, 0.20 to 1.66; $p = 0.013$) had milder declines in PM T compared to men having sex less than weekly (Fig. 2B) . ΔAM T was unrelated to sexual behavior ($p > 0.4$). Models for residualized ΔAM T and PM T were non-significant (both $p > 0.5$), representing a discrepancy between absolute and residualized ΔPM T results.

Among subjects transitioning from being non-married and childless at baseline to newly married first-time fathers at follow-up ($n = 153$), ΔAM T did not significantly relate to sexual intercourse frequency ($p > 0.3$), including after adjustment for potential confounding factors ($p > 0.3$; see below). ΔPM T was positively associated with sexual intercourse frequency [model: $F(df\ 2, 152) = 5.11$; $R^2 = 0.064$; $p = 0.007$]. Newly married new fathers engaging in sex 3+ times per week (pairwise comparison, 95% CI: 0.77, 0.28 to 1.25; $p = 0.002$) had milder decreases in PM T compared to men having sex less than weekly (Fig. 2C). This finding had a medium effect size (Cohen's $d = 0.74$). We adjusted the models for a series of sociodemographic variables we hypothesized might confound relationships between ΔT and sexual activity, including: duration of marriage, number of children, paternal childcare involvement, cosleeping, and change (2005 to 2009) in stress and total sleep. Fathers with younger children had larger decreases in PM T ($p = 0.011$). All other controls were not significant ($p > 0.2$). The effect size for sexual activity modestly declined (F: 4.11; $p = 0.018$) with all confounders included. The model for residualized ΔAM T was non-significant ($p > 0.1$), while sexual activity and residualized ΔPM T were significantly related [model: $F(df\ 2, 152) = 5.70$; $R^2 = 0.071$; $p = 0.004$]. Newly married new fathers reporting sex 3+ times per week had milder declines in PM T compared to those reporting sex less than weekly (pairwise comparison, 95% CI: 0.79, 0.31 to 1.28; $p = 0.001$) and 1–2 times per week (0.71, 0.25 to 1.18; $p = 0.003$).

Correlations between T and sexual behavior could reflect an effect of T on behavior, of behavior on T, or both. As mentioned in Material and methods, one local cultural factor that limits our ability to examine these issues longitudinally is the rarity of intercourse among young adults prior to marriage in Metro Cebu (Table 2) (Medina, 2001; Upadhyay et al., 2006). Among men in the sample, those transitioning to being newly married new fathers (follow-up), very few reported having sex once ($n = 12$) or 2+ times ($n = 12$) per week at baseline, prior to marriage (see Table 2). Thus, to allow adequate cell sizes to explore the hypothesis that baseline (2005) sexual activity predicts ΔT, we combined these categories, yielding a variable delineating men based on whether they had at least weekly intercourse in 2005. Men ($n = 24$) who engaged in weekly sexual intercourse at baseline had less of a decline in PM T between 2005 and 2009 [model $F(df\ 1, 152) = 8.31$; $R^2 = 0.052$; $p = 0.005$] than men who did not have frequent intercourse prior to marriage/fatherhood (pairwise comparison, 95% CI: 0.63, 0.20–1.05). Indeed, newly married new fathers who reported weekly intercourse at both time points ($n = 18$) had less pronounced declines in PM T compared to other men in this sub-group [model

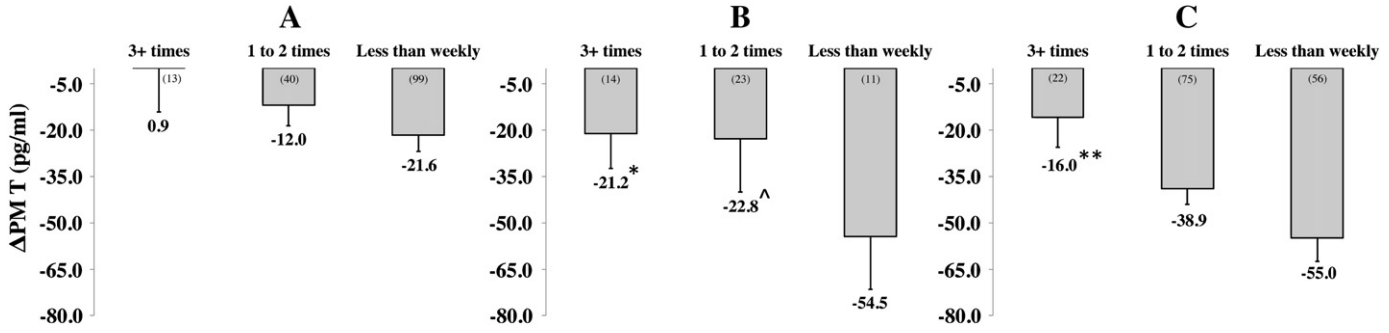

Fig. 2. A–C. Changes (Δ) in PM T values (2005 to 2009) based on sexual intercourse frequency at follow-up (less than weekly, 1–2 times per week, 3+ times per week). Panels stratified according to marital and parenthood status. Values were adjusted for time of saliva collection. Sample sizes in parentheses at column bases. Panel 2A($n = 152$): unmarried and childless at baseline and follow-up. Panel 2B ($n = 48$): unmarried and childless at baseline, newly married with no offspring at follow-up. Subjects reporting sex 1–2 times per week (^$p = 0.015$) and 3+ times per week (*$p = 0.013$) differed from those engaging in sex less than weekly, only after controlling for duration of marriage (see Results for full model details). Panel 2C ($n = 153$): unmarried and childless at baseline, newly married first-time fathers at follow-up. Subjects reporting sex 3+ times per week differed from those engaging in sex less than weekly (**$p = 0.002$).

F(df 1, 152) = 13.76; R^2 = 0.084; p = 0.0003], differing by almost a full standard deviation (pairwise comparison, 95% CI: 0.89, 0.42–1.37) and representing a large effect size (Cohen's d = 0.94).

We then tested whether married fathers (at both baseline and follow-up; n = 80) with only modest declines in T over the study period reported more frequent intercourse at follow-up. In this group, neither ΔAM T nor ΔPM T related to sexual activity (both p > 0.5). After adjustment for potential confounding variables (see analyses for newly married new fathers), ΔAM T and ΔPM T remained non-significant (p > 0.2). Married fathers (2005 & 2009) did not experience milder declines in T based on having had frequent intercourse at baseline (p > 0.8) or in both 2005 and 2009 (p > 0.4). Models for residualized ΔT were also non-significant (both p > 0.6).

Lastly, we evaluated whether T was related to extra-pair intercourse. In the sub-sample of eligible subjects (n = 245; see Material and methods), eighteen men (7%) reported at follow-up having had intercourse with someone other than their partner in the prior year. ΔAM T or ΔPM T did not predict higher infidelity (both p > 0.2), and, examining cross-sectional relationships, we found no difference for follow-up AM T (p > 0.9) or PM T (p > 0.1) based on self-reported infidelity.

Discussion

Men with elevated T are thought to engage in status-seeking, risk taking, and competitive behaviors that might increase mating opportunities but could be incompatible with certain aspects of parenting and romantic commitment (Alvergne et al., 2010; Dabbs and Morris, 1990; Edelstein et al., 2011; McIntyre et al., 2006; Mehta and Josephs, 2010; Pollet et al., 2011; Ronay and von Hippel, 2010; Roney et al., 2007). Indeed, among US military personnel, higher T men commit more infidelity and experience greater marital disruption (Booth and Dabbs, 1993; Mazur and Michalek, 1998). Men with elevated T also express less sensitivity to infant cries (Fleming et al., 2002). By contrast, fathers with lower T engage in more childcare (Alvergne et al., 2009; Muller et al., 2009) and some studies suggest that men's T acutely declines when they express nurturing parenting behaviors (van Anders et al., 2012) or interact directly with their children (Storey et al., 2011), but see also (Gettler et al., 2011b; Gray et al., 2007). We have found complementary results in prior analyses from this sample, as men experienced longitudinal declines in T during marital and parenthood transitions and had lower T when they reported performing hands-on childcare (Gettler et al., 2011a). In the present study we provide further, novel evidence that potentially aligns with this model. Using longitudinal data collected over a 4.5-year period, we found that men with more dramatic reductions in T during the transition to marriage and first-time fatherhood had less frequent sexual intercourse with their partners at follow-up, compared to men with milder decreases in T. In addition, we also showed that a sub-group of subjects who had frequent intercourse prior to marriage and fatherhood, as well as after becoming newly married new fathers, experienced more modest declines in T. These findings raise the possibility of bi-directional relationships between T and men's sexual behavior, an observation that is increasingly emphasized in other domains of psychobiology (van Anders and Watson, 2006).

Among the men in our sample, those experiencing larger declines in T (ΔT) during the transition to marriage and first-time fatherhood reported lower sexual intercourse frequency in the context of their committed relationships, compared to men showing more modest T decreases. T is necessary for the initiation and maintenance of sexual behavior in many non-human species (Hull and Rodriguez-Manzo, 2009), and hypogonadal men generally report reduced sexual desire and sexual activity, compared to males with normal-functioning reproductive physiology (Isidori et al., 2005). However, prior studies of healthy men with normal T have generally not found robust relationships between T and sexual activity/desire (Brown et al., 1978; Persky et al., 1978; Raboch and Stárka, 1973; van Anders, 2012). Our longitudinal design, examining ΔT in the same individuals through time during seminal life history transitions, potentially provides an analytical advantage unavailable in cross-sectional research (Duncan et al., 1998; Williams, 2008), though it is also notable that our sexual intercourse measure in many analyses reflects reports at follow-up, rather than a true change variable (see limitations below).

Among newly married non-fathers, marriage duration confounded the relationship between ΔT and intercourse frequency. After controlling for marriage length, we showed that newly married men with more modest declines in PM T had sex more frequently at follow-up. However, it should be noted that the confidence intervals in these models were wide, indicating imprecision in the point estimates, likely due to small sub-sample sizes. Moreover, after we removed the effects of baseline T on longitudinal change in T, these results were no longer significant. There are several possible explanations for this discrepancy between models in this sub-sample. One is that the variable results between absolute and residualized change in T could simply be due to regression to the mean, i.e. the fact that men with higher baseline T are more likely to show larger longitudinal declines in T as a mere statistical artifact. Although this explanation might account for baseline-change in T correlations, it fails to explain why an artifactual pattern would relate to a psychobiological outcome (sexual activity). Alternatively, high baseline T might be causally linked to lower sexual activity at follow-up. Because baseline values and change scores are correlated, this could lead to confounding between absolute change in T and sexual behavior. However, this explanation is incongruent with the known relationships between T and male reproductive/competitive behavior. For example, we previously showed that single non-fathers with elevated T at age 21.5 years were more likely (than their lower T peers) to be married by age 26 (Gettler et al., 2011a), consistent with an effect of T on competitive or mating-related characteristics. Given this finding and the extensive literature documenting the role of T in male reproduction and mating behaviors across species, it seems unlikely that high baseline T would incline males toward low sexual activity with their partners. The third possibility is that large declines in T do in fact drive (or are strongly inter-related with) lower sexual activity. In this scenario, high baseline T would serve as a marker of males who experience a larger subsequent rate of T decline and who, as a result, are likely to report engaging in lower sexual activity at follow-up. Because there is a theoretical and empirical expectation that large, within-individual decreases in T could incline men toward lower sexual activity, adjusting for baseline T might represent over-controlling. In this scenario, the model that includes absolute change in T, without controlling for baseline T, would be the appropriate characterization of the relationship between T and sexual behavior. Future studies including more frequent sampling of T and sexual behavior as men experience relationship transitions will be necessary to clarify the causal inter-relationships between T and sexual behavior more definitively.

Among newly married new fathers, men with relatively small decreases in T reported the highest intercourse frequency. This result had a medium effect size and was largely unchanged after controlling for factors that we hypothesized might confound or mediate relationships between ΔT and couples' sexual intercourse frequency in this cultural setting, including duration of marriage, paternal childcare, cosleeping, number of children, and the age of their youngest offspring as well as changes in sleep quality or psychosocial stress. It bears mentioning that our control variables for sleep quality and stress may not fully capture the extent to which some families experience sleep disruption and psychosocial adversity when raising young children. Both factors could independently affect ΔT and couples' sex lives, and their rigorous measurement should be a goal for subsequent studies in this area, with attention paid to potential cross-cultural variation (e.g. Hewlett and Hewlett, 2010). Identifying psychobiological factors that might be in the pathway between ΔT and sexual activity is also imperative. Specifically, we did not have measures of men's sexual desire/libido, which we suggest could relate to both ΔT following marriage and first-time fatherhood and lower frequency of intercourse. The

implications of reduced T for sexual function/performance also merit consideration in future research (Aversa et al., 2000; Traish et al., 2007).

Based on theoretical expectations regarding T and male reproductive strategy (Wingfield et al., 1990), it is plausible that the dampening of new fathers' sexual behavior in connection with reduced T is an integrated part of a suite of psychobiological characteristics that collectively attunes fathers' attention more acutely to the needs of their offspring (Gettler, 2010; Gray and Anderson, 2010; van Anders, 2013; van Anders et al., 2011). Although longitudinal data are sparse, in some mammalian species with biparental care, fathers' changes in T appear closely calibrated to the species' pace of life history, with males' T being elevated near their partners' estrus/periovulatory period to promote mating in the post-partum period (Juana et al., 2010; Nunes et al., 2000; Reburn and Wynne-Edwards, 1999; Ziegler et al., 2004). Given the extent to which human parents' sexual behaviors are likely to be affected by factors at the individual-, family-, political economic-, and cultural-levels, shifts in contemporary human paternal T and sexual behavior seem unlikely to be closely coupled to "life history pacing" in a similar manner. We see some evidence for this in the present analysis, as new fathers with young children showed greater declines in T, but this did not mitigate the relationship between ΔT and intercourse frequency.

A functional rationale is less obviously apparent for our findings among newly married *non-fathers*, who likewise experienced declining T and reduced sexual behavior. Theoretically, diminished T production in newly married childless men is thought to improve their functioning as partners, with benefits to their marital relationship quality via heightened partner focus, nurturance, and fidelity. Such an effect might help to solidify the pairbond in advance of having offspring. Consistent with this perspective, prior US-based research has linked high T to greater divorce risk (Mazur and Michalek, 1998). To the extent that reduced T contributes to enhanced relationship quality, research suggests this should increase couples' intercourse frequency (Costa and Brody, 2007; Rao and Demaris, 1995), contrary to our findings. Moreover, in US studies, married/cohabitating partners who have less intercourse separate at higher rates than more sexually active couples (Yabiku and Gager, 2009), suggesting that if reduced T contributes to less frequent intercourse the net result could be lower pair stability. This is consistent with the suggestion that lower T might not be uniformly advantageous in terms of men's behaviors as committed partners and invested parents, likely differing based on the context and variable demands of these social roles (van Anders, 2013; van Anders et al., 2011). The possible interconnections between ΔT, changes in sexual behaviors, and marital relationship quality and how these factors coalesce in varying cultural contexts are worthwhile focal points for future research.

Also notable, as we previously reported, mothers at Cebu have lower T than non-mothers, especially in the first year post-partum (Kuzawa et al., 2010), findings that were recently replicated elsewhere (Barrett et al., 2012). The relationships between reduced maternal T and changes in female sexual behavior or libido remain unexplored but also merit further consideration. An integrated family system perspective, examining the nexus between spousal partners' hormones, sexual desire, and receptivity, would also likely be fruitful (Hipp et al., 2012; Persky et al., 1978).

Subjects who became newly married new fathers between baseline and follow-up and who reported weekly intercourse at both time points experienced significantly smaller declines in T relative to other newly married new fathers, which represented a large effect size. Although this relationship should be interpreted cautiously in light of the relatively small sample and correspondingly imprecise point estimate, it could indicate that engaging in frequent sexual activity both before and after the transition to marriage and fatherhood helps men maintain T production compared to their peers who have less frequent sex.

To our knowledge, no study has shown that frequent sexual activity contributes to elevated T production over an extended period of time, such as the multi-year duration of our study. However, T is known to increase acutely after sexual intercourse and orgasm, with the upregulation of T observable hours later (Dabbs and Mohammed, 1992; Escasa et al., 2011), overnight (Hirschenhauser et al., 2002), and perhaps as long as 24-to-48 hours afterward (Knussmann et al., 1986; Kraemer et al., 1976). Thus, one possible explanation for our findings is that more of the men reporting frequent intercourse engaged in sexual activity close in time to the follow-up saliva sampling. This could temporarily elevate T at follow-up, thus reducing the apparent average decline in T over the study period for this group as a whole. In our sample, few men (14%) reported sexual intercourse during the 24-hour span around the 2009 saliva collections, and men reporting sexual activity in this time frame did not differ significantly from other subjects for PM T or ΔT (not shown). Incorporating recent (24 h around sampling) sexual intercourse activity into our analyses did not alter the results (not shown). Future research incorporating fine-grained temporal resolution measures of both T and sexual activity will be needed to tease apart the causal pathways that underlie these psychobiological relationships. Although our findings should be considered preliminary, they provide a rationale for additional research in this domain.

In the present analysis, we documented significant relationships primarily between sexual activity and PM T, which is similar to our results from prior analyses from this sample in which hormone–demographic correlations tended to be exclusive to or stronger with PM T (Gettler et al., 2011a, 2012a; Kuzawa et al., 2009). Although findings do vary, it has been argued that AM T levels reflect circadian-sleep biology and less sensitivity to social stimuli in humans and other hominoids whereas PM T is more responsive to social and behavioral context (Muller and Wrangham, 2004). It might also be the case that the generally steeper declines in T during the morning hours obfuscate relationships with social factors and behaviors, compared to the more stable measures of PM T (van Anders et al., 2013). Whether the differential implications of AM T and PM T for male psychobiology have to do with circadian rhythms in receptor expression/sensitivity or circadian fluctuations in other neurobiological–hormonal signals that interact with the hypothalamic–pituitary–gonadal system to influence psychobehavioral profiles, particularly sexual behavior, remains to be determined (Hampp et al., 2008; McClung, 2007; Yang et al., 2006).

This study has limitations that warrant discussion. First, our study measured T and men's reports of sexual intercourse frequency at two time points that were separated by 4.5 years. While this multi-year period of follow-up allowed for detectable changes in men's social status and hormonal profiles to accrue, the resolution of our data likely contributed to imprecision in some of our point estimates. Notably, the sexual activity questions asked to men at baseline and follow-up differed in both their phrasing and the scope of time over which subjects reported their sex behaviors. As illustrated in our data, and also by previous authors, in the cultural context of Metro Cebu, only a small number of subjects report frequent intercourse as young adults, prior to marriage or cohabitation (Upadhyay et al., 2006). In addition to challenges in reconciling differences in the question formats across surveys, the infrequency of intercourse at baseline limited our ability to examine change in sexual activity over the study period as our outcome of interest. We think it unlikely that this low level of reported pre-marital intercourse frequency is a function of the baseline question format, but, rather, is consistent with generally conservative sexual mores in this setting (Medina, 2001; Upadhyay et al., 2006). Relatedly, it is also plausible that social desirability could have contributed to under-reporting of pre-marital intercourse prevalence, though it has been suggested that this is more applicable to Cebuano females than males (Upadhyay et al., 2006).

There are methodological issues regarding key covariates in our study that bear discussion. Given that this is a large, longitudinal survey that has followed individuals repeatedly for 30 years, visits are designed to minimize participant burden. We were thus not able to validate questions on typical daily routines, such as those pertaining to duration of

daily paternal care. Previously, we have shown that fathers reporting no direct childcare have elevated T relative to those performing greater paternal care (Gettler et al., 2011a). Based on cross-species expectations (Wingfield et al., 1990) and findings from other cultural contexts (Alvergne et al., 2009; Muller et al., 2009), these results give us confidence that our measures capture socially meaningful variation in caregiving practices. Similarly, while we controlled for change in total sleep time, our measures in this domain were somewhat limited. Self-reported sleep time has been linked to poor long-term health outcomes in some studies, but it has been shown to have modest validity as a marker of sleep quality, when compared to objective measures, such as actigraphy (Lauderdale et al., 2008). Lastly, because of limited statistical power, we were not able to formally test for statistical interactions between sexual behavior and group status. As such, any ostensible group differences based on models conducted separately (by group) should be taken as preliminary and require follow up with a larger study that has sufficient statistical power to test for heterogeneity across groups.

Conclusions

In sum, we found that newly married new fathers who experienced greater declines in T also reported less frequent sexual intercourse with their partners at follow-up, 4.5 years later. We also showed that men who engaged in frequent sexual activity both before and after becoming married fathers experienced milder declines in T compared to less sexually active men, which suggests that sexual behavior could also have long-term implications for T production. This finding is consistent with the increasingly recognized observation that relationships between hormones and social behavior are likely reciprocal, rather than uni-directional. To our knowledge, these results are the first longitudinal evidence relating marriage/fatherhood-driven T decreases to men's sexual behavior.

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