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Short-term changes in fathers' hormones during father–child play: Impacts of paternal attitudes and experience

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ABSTRACT

Hormonal differences between fathers and non-fathers may reflect an effect of paternal care on hormones. However, few studies have evaluated the hormonal responses of fathers after interacting with their offspring. Here we report results of a 30-minute in-home experiment in which Filipino fathers played with their toddlers (n = 42, age: 2.6 ± 0.8 years) and consider whether paternal experience and men's perceptions of themselves as fathers affect hormonal changes. Fathers provided saliva and dried blood spot samples at baseline (B) and 30 (P30) and 60 (P60, saliva only) minutes after the interaction. We tested whether testosterone (T), cortisol (CORT), and prolactin (PRL) shifted after the intervention. In the total sample, T did not vary over the study period, while CORT declined from B to P30 and P60, and PRL also declined from B to P30 (all $p<0.001$). Fathers who spent more time in daily caregiving ($p<0.05$) and men who thought their spouses evaluated them positively as parental caregivers ($p<0.01$) experienced a larger decline in PRL (B to P30) compared to other fathers. First-time fathers also had larger declines in PRL compared to experienced fathers ($p<0.05$). Experienced fathers also showed a greater decline in CORT (B to P60) compared to first-time fathers ($p<0.05$). These results suggest that males' paternal experience and age of offspring affect hormonal responses to father–child play and that there is a psychobiological connection between men's perceptions of themselves as fathers and their hormonal responsivity to childcare.

Introduction

Humans are relatively unique among mammals in that fathers frequently invest heavily in raising offspring and, particularly, provide direct care to children (Geary, 2000; Gray and Anderson, 2010; Kleiman and Malcolm, 1981). As a consequence, human fathers must manage time and energetic trade-offs between mating and parenting effort, as is true for other species in which paternal care is common (Clutton-Brock, 1991; Kleiman and Malcolm, 1981; Stearns, 1989; Trivers, 1972). Studies exploring the hormonal mechanisms underlying transitions between these conflicting components of reproductive strategy have focused in particular on the behavioral and physiological effects of testosterone (T) and prolactin (PRL), and, to a lesser degree, cortisol (CORT) (Wingfield et al., 1990; Wynne-Edwards, 2001).

T is an androgenic steroid produced by the hypothalamic–pituitary–gonadal (HPG) axis that modulates behaviors related to reproduction and conspecific interaction (Nieschlag and Behre, 2004). Because it is anabolic for skeletal muscle and promotes behaviors related to territoriality, dominance, libido, and courtship (Archer, 2006; Bribiescas, 2001; Hart, 1974), T is understood as facilitating males' mating effort, often at the expense of paternal investment (Gray and Campbell, 2009; Gray et al., 2002; Wingfield et al., 1990). Consistent with this expectation, numerous human studies have shown that fathers have lower T compared to single non-fathers (Gettler et al., in press; Gray et al., 2006; Kuzawa et al., 2009; Muller et al., 2009).

Prolactin (PRL), a peptide hormone released from the anterior pituitary, is best known for its role in milk production during lactation and as a facilitator of maternal nurturing behavior (Freeman et al., 2000; Numan and Insel, 2003). In males, PRL has been shown to increase with paternal care in multiple avian and mammalian species (Ziegler, 2000), and, in non-human primate fathers, PRL appears to facilitate weight gain in anticipation of paternal care, thus helping buffer fathers from the energetic costs of parenting (Ziegler et al., 2009). In human males, there is evidence that PRL is implicated in paternal care, as fathers with higher baseline PRL have been shown to engage in more exploratory play with their children (Gordon et al., 2010b) and to be more responsive to infant cries (Fleming et al., 2002).

The glucocorticoid cortisol (CORT), which is primarily produced by the hypothalamic–pituitary–adrenal (HPA) axis, is also increasingly posited to be a regulator of some maternal behaviors and attachment (Wynne-Edwards, 2001; Ziegler, 2000), including in human

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mothers (Fleming et al., 1987, 1997). However, the role of CORT in human fathering is poorly characterized. Fathers with more lifetime experience caring for children have been found to have lower CORT (Fleming et al., 2002), while baseline CORT has been shown to be lower in partnered fathers compared to single non-fathers in the Philippines (Gettler et al., 2011). Expectant fathers' CORT appears to peak in the weeks before their partners' give birth, then falling off drastically post-partum (Berg and Wynne-Edwards, 2001; Storey et al., 2000). Thus, these existing studies suggest a potential role for CORT in human fathering, though the hormone's possible involvement with paternal care, emotions, and attachment are not well understood.

Much of the prior work on human paternal socioendocrinology has focused on single hormonal measurements, or averages collected across several days, which therefore identify relatively stable hormonal differences between fathers and non-fathers (Alvergne et al., 2009; Gettler et al., 2011; Gray, 2003; Gray et al., 2002, 2006; Kuzawa et al., 2009; Muller et al., 2009). Hormones are notable, however, for the speed with which they respond to changes in socio-behavioral context (van Anders and Watson, 2006), which has inspired a small but growing number of studies investigating acute hormonal responses to social stimuli, including to childcare. For example, while it is well known that oxytocin and PRL rise in mothers during breastfeeding (Heinrichs et al., 2001; McNeilly et al., 1983), recent studies have also shown that mothers who provide affectionate care to their children show oxytocin increases after interacting with them (Feldman et al., 2010) as do mothers who have secure adult attachments (Strathearn et al., 2009). It has likewise been demonstrated that maternal infant holding can induce short-term declines in mothers' CORT (Heinrichs et al., 2001), particularly during skin-to-skin care among new mothers (Mörelius et al., 2005).

Few similar studies have evaluated hormonal responses of human fathers to child interaction, but findings to date support a similarly acute responsiveness to infant cues or direct interaction, with the direction and magnitude of hormonal responsivity often depending upon a range of individual characteristics. For instance, studies report that a father's hormonal response to child interaction varies based on whether he lives with his children (Gray et al., 2007), whether he has spent time with his children on the day of sampling (Storey et al., in press), whether he is a first-time father (Delahunty et al., 2007), and whether he plays with his child in a stimulatory manner (Feldman et al., 2010). Other studies suggest that a man's psychological disposition (e.g. aggressive vs. docile; dominant vs. passive) can influence acute hormonal responses to social stimuli (Suarez et al., 1998; van der Meij et al., 2008; Wirth and Schultheiss, 2006). However, to date, there has been little consideration of the psychobiological connections between hormonal reactivity and fathers' socio-emotional characteristics, such as attitudes about paternal roles and men's relationships with their spouses in terms of childcare duties, which may have implications for the ways in which they respond physiologically to contact with their children.

Here we sought to clarify hormonal responses of fathers to interacting with their child by examining T, PRL, and CORT before and after men (age 26.6 ± 0.3 [SD] years; n = 42) spent 15–30 min playing with one of their young children in their home. Our study drew on a sample of fathers residing in and around Cebu City (Philippines), where it is common for men to be involved in daily care of their children (ECD et al., unpublished data.; Gettler et al., in press; Kuzawa et al., 2009). Based on prior human and non-human primate research, we hypothesized that T and CORT would significantly decline and PRL would significantly increase after the father–child interaction. We also tested whether fathers showed different patterns of hormonal change based upon: a) being a first-time father; b) being a father to an infant [1 year old or less]; and c) their self-reported daily caregiving involvement. Finally, we assessed how men's "caregiving identity" (how important it is for a father to be a caregiver to his child) and "perceived reflected-appraisals" (how a father perceives his partner's evaluation of him as a caregiver) (Maurer et al., 2001) affected hormonal responses to child interaction.

Methods

Study population

Data were collected in 2009 and 2010 as part of the Cebu Longitudinal Health and Nutrition Survey (CLHNS), a population-based birth cohort began in 1983–84. Men were a mean of age 26.6 ± 0.3 (SD) years at the time of data and sample collection in 2010. Socioeconomic, demographic, health and general behavioral data were collected using questionnaire-based, in-home interviews administered by Cebuano-speaking interviewers (Adair et al., 2010). Weight (kg) and height (cm), and triceps and suprailiac skinfold thicknesses (mm) were measured using standard anthropometric techniques. Percent body fat was calculated from triceps and suprailiac skinfold thicknesses using body density estimates and a body composition predictive formula (Durnin and Womersley, 1974; Lohman et al., 1988). The body mass index (BMI) was calculated as the ratio of weight (kg)/height (m^2). Self-reported psychosocial stress in the month preceding sampling was quantified via a modified version of the 10-item Perceived Stress Scale (PSS) (Cohen et al., 1983). Participants provided ratings of their self-perceived psychosocial stress on the day of sampling in response to the question "How stressful was your day today?" using a 5-point scale, ranging from "Not stressful at all" to "Very stressful." Men similarly rated their sleep quality, pertaining to the night before the interview, using a 5-point scale ranging from "I slept very poorly" to "I slept very well." This research was conducted under conditions of informed consent with human subjects' clearance from the Institutional Review Boards of the University of North Carolina, Chapel Hill and Northwestern University.

Sample characteristics

During the 2009 survey, 908 males of the original cohort of 1633 liveborn males were located and interviewed. 451 of these men were fathers. In 2010, fathers were selected for the father–child interaction study based on living with at least one biological child, older than 1 year of age and less than 4 years of age, and the mother of that child, having no adopted or step-children, and having full data from the 2005 and 2009 CLHNS surveys. A sample of 164 met these criteria. Because of budgetary constraints and the size of the Cebu metropolitan area, sampling was restricted to 23 local barangays (neighborhoods), compared to 135 barangays in the 2009 survey, resulting in a final sample of 45 men who agreed to participate. Two subjects were excluded because of CORT values 6+ SD above the mean of the sample, while a second subject was excluded for having PRL that was 11 SD above the sample mean and having undetectable CORT. Unpaired t-tests were used to compare original cohort data (1983–1984) for the 42 men in this analysis and excluded individuals. Men in this sub-sample were born to slightly less educated mothers (average grade completed: 6th grade vs. 8th grade; $p<0.05$), but did not differ from excluded individuals on household income, household size, birth order, mother's height, or birth length and weight (all $p>0.2$). In comparisons between this sub-sample of men (2010) and the full sample of CLHNS men (2009), our substudy fathers were similar in height (162.6 vs. 162.9 cm) but had slightly greater BMI (mean: 23.7 vs. 22.7 kg/m^2; $p<0.1$). They had also achieved a comparable level of education (mean: 10th grade). As of 2009, compared to other CLHNS married fathers, men in our sample had been married longer (mean: 4.8 vs. 3.8 years; $p<0.01$) and had been fathers for a comparable duration (3.7 vs. 3.3 years; $p>0.2$), with more children on average (2.2 vs. 1.6; $p<0.0001$).

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Paternal caregiving

The 20 paternal caregiving behaviors about which fathers were asked were drawn from a previous large-scale survey on male parenting behaviors in the Philippines (ECD et al., unpublished data.). Examples of the caregiving behaviors included: feeding children, playing, bathing children, reading to children, and walking children to school. Men were asked to estimate how much time they had spent on each activity in the last 7 days and specifically on the day of the interview. We later calculated the average hours of caregiving per day.

Paternal caregiving identity and perceived reflected-appraisals

“Caregiving identity” was defined as how important it was to a father that he was a committed caregiver to his child, whereas “perceived reflected-appraisals” were how a father perceived his partner's evaluation of him as a parental caregiver (Maurer et al., 2001). For the latter, the higher a man's score the more positively he felt his partner viewed him as a caregiver. These parental role scales were derived from a modified version of a questionnaire instrument known as the “Caregiving and breadwinning identity and reflected-appraisal inventory” (Maurer et al., 2001), which consists of a series of multiple-choice questions, each on a 5-point scale. Men's responses to these questions were tallied and then averaged, yielding a mean score on each scale (caregiving identity: 4.4 ± 0.6; perceived reflected-appraisals: 3.6 ± 0.3). The measure of internal consistency, Cronbach's alpha, for the caregiving identity scale was $\alpha = 0.80$ and for the perceived reflected-appraisal scale was $\alpha = 0.70$.

Father–child interaction protocol

An interviewer arrived at the subject's home in the early afternoon. Men were screened for alcohol consumption in the previous 12 h and for eating, cigarette smoking, or participating in rigorous activity in the hour prior to the interviewer's arrival. Interviewers also noted whether men were interacting with any of their children upon arrival. Before the interview began, all other individuals, including the men's wives and other children, were asked to leave the room. In the first hour of the home visit, men were consented and the questionnaire-based interview was initiated. After this preliminary hour, men provided an initial set of saliva/DBS samples (see below), and then were asked to play with their child for up to 30 min. All children were provided a gift of a medium-sized plastic ball, and fathers were asked to use this toy during the interaction. Upon completion of the interaction, interviewers proceeded with the interview process, collecting additional samples at 30 min (saliva/DBS) and 60 min (saliva only).

Saliva and dried blood spot (DBS) collection protocol

After a preliminary hour interview, men provided a saliva sample in a polypropylene tube and then an interviewer-administered DBS sample (before interaction: baseline [B] samples) following standard collection procedures (McDade et al., 2007). The average time for the first saliva collection was 1:46 PM $\pm$ 43.6 min. Upon completion of the DBS collection, interviewers set a timer for 30 min. Fathers were then asked to interact with their child. Duration of the father–child interaction averaged 24.1 ± 5.5 min (range: 15–30 min). When the 30-minute timer finished, men provided a second saliva and DBS sample (post-30-minute [P30] samples). The average time between B and P30 for saliva samples was 41.4 ± 4.0 min and between DBS samples was 41.6 ± 4.2 min. Upon completion of the DBS collection, interviewers again set a timer for 30 min. During the interim, interviewers continued with the administration of the questionnaire. When the 30-minute timer finished for the second time, men provided a third saliva sample (post-60-minute [P60] samples). The average time between B and P60 saliva samples was 73.6 ± 6.0 min. All samples were transported to the University of San Carlos in Cebu City, where they were frozen at −35 C. All samples were shipped on dry ice to Northwestern University, where they were stored at −35 C (DBS) and −80 C (saliva).

Salivary T and CORT

Salivary T (pg/mL) and CORT (μg/dL) assays were run at the Laboratory for Human Biology Research (LHBR) at Northwestern University. Concentrations of T were determined using an enzyme immunoassay protocol developed for use with saliva samples (Salimetrics, State College, PA; Kit No. 1-2402). The inter-assay coefficients of variation for T were 6.4% and 7.2% for high and low control samples, respectively.

Concentrations of CORT were determined using an enzyme immunoassay protocol developed for use with saliva samples (Salimetrics, State College, PA; Kit No. 1-3002). The inter-assay coefficients of variation for CORT were 2.8% and 3.3% for high and low control samples, respectively.

Dried blood spot PRL

PRL (ng/mL) assays were run at the LHBR using a commercially available kit designed to measure PRL from plasma (Diagnostic Systems Laboratories # 10-4500). We modified this assay for use with DBS based on a previously validated protocol for the same procedure (Gray et al., 2007). The inter-assay coefficients of variation for PRL were 8.5% and 8.9% for high and low control samples, respectively.

Statistical analyses

All analyses were conducted using version 10 of Stata (Stata Corporation, College Station, TX). We created a dichotomous variable separating fathers with infants (child 1 year old or less; $n = 11$) and men whose children were all older than 1 year ($n = 31$). We first tested for correlations between hormonal values taken at the same time (B, P30, P60). We then tested for correlations between baseline (before-interaction) hormone levels and demographic, anthropomorphic, and stress-related covariates. Because multiple comparisons were used to assess differences in T and CORT, we used a Bonferroni correction for multiple comparisons, by dividing the alpha level (0.05) by the number of comparisons (3), yielding a corrected alpha level of 0.02.

We then used multiple linear regression to predict changes in hormones between B and P30 (T, CORT, PRL) and B and P60 (T, CORT) based on fatherhood-related variables. The dependent variables for these regression models were “partialed change” values, which were yielded by regressing P30 or P60 values on B (all adjusted for time of sampling and wake time the day of sampling) and then using the resulting regression coefficient (β) in the following formula, e.g. [$P30 - (\beta * B)$]. By using this approach we effectively predicted the change in hormone levels between time periods (e.g. B to P30 or B to P60) while removing the effect that baseline hormonal values had on the magnitude of raw change scores (Cohen, 2003). Models were also adjusted for the duration of father–child interaction. Caregiving identity and perceived reflected-appraisals were highly correlated ($r = 0.51$; $p < 0.001$), so they were not included in models together to avoid multi-collinearity. Unless otherwise noted, statistical significance was evaluated at $p < 0.05$. All statistical tests were two-tailed.

Post-hoc we used unpaired t-tests to evaluate differences between first-time and experienced fathers on hours of caregiving prior to the interview, on the day of sampling. Using Fisher's exact test, we also assessed whether these groups differed on daily levels of physical care to their young children (less than 4 years old). Finally, we tested for correlation between perceived reflected-appraisals and hours of caregiving on the day of sampling, prior to the interview.

Results

Table 1 summarizes the demographic, socioeconomic, and anthropometric characteristics of the study fathers. Men in this sample had healthy body composition (mean BMI: 23.7 kg/m^2; mean body fat %: 18.9) by standards for East Asian populations (Gallagher et al., 2000). The majority (79%) of men had not completed high school, having reached the 10th grade on average. All men in the sample were married and had been so for an average of 5.4 years and had been fathers for 4.4 years. Fathers' reports of daily caregiving (mean: 4.70 h per day) were relatively high compared to data collected in other cultural and ecological contexts (Gray and Anderson, 2010; Hewlett, 1992; Lamb, 2004).

We first tested for correlations between T, CORT, and PRL (all adjusted for time of sampling and wake time the day of sampling). Consistent with our prior findings in the full sample (Gettler et al., 2011), men with higher T generally had higher CORT at B ($r = 0.35$) and P30 ($r = 0.35$) (both $p < 0.05$). PRL was not significantly correlated to either T or CORT at any time point (all $p > 0.2$). We next tested for associations between hormone levels at baseline and variables reflecting socio-economic status, anthropometry, psychosocial stress, and sleep quality (Table 2). Fathers who had been married longer had lower T ($p < 0.05$) while men who reported psychosocial stress on the day of the interview, prior to sampling, had higher T ($p < 0.05$). CORT was lower in men with greater adiposity and men who had completed more years of education (both $p < 0.05$).

We then used paired t-tests to test for significant within-individual changes over the intervention period in T, CORT, and PRL (Figs. 1a–c). T did not vary over the 3 sampling times (both $p > 0.2$). Men's CORT significantly declined from B to P30 and B to P60 (both $p < 0.001$). Men also experienced a significant decrease in PRL from B to P30 ($p < 0.001$).

Finally, we regressed change in T, CORT, and PRL, respectively, (all adjusted for time of sampling and wake time the day of sampling), controlling for the duration of the father–child interaction, on a series of variables that we hypothesized could help explain between-individual variation in the patterns of hormonal changes during the father–child play period. The independent variables for these analyses were: hours of daily paternal caregiving, caregiving identity, perceived reflected-appraisals, father of an infant, and paternal experience (first-time vs. experienced father). We first regressed each hormone on the independent variables individually in base models (e.g. Table 3; Models 1–5) and then considered all the variables in a collective model (e.g. Table 3; Model 6). In light of recent evidence (Storey et al., in press), we assessed whether caregiving prior to the interview on the day of sampling predicted hormonal responses in our subjects, finding no effect of recent care on changes in PRL, T, or CORT between B and P30 or P60 (all $p > 0.3$). Caregiving prior to the interview also did not substantially affect the regression results (below) and was therefore excluded from these models.

When change in PRL was predicted from daily care, men engaging in more caregiving showed a greater decline in PRL between B and P30 ($p < 0.05$; Table 3, Model 1) compared to men who performed less childcare, but this result became non-significant ($p > 0.15$) when all of the independent variables were considered collectively (Table 3, Model 6). PRL decreased more in men who felt their wives viewed them positively as caregivers compared to men who thought their spouses evaluated them less positively ($p < 0.01$; Fig. 2; Table 3, Model 3). These effects remained significant when other independent variables were included ($p < 0.05$; Table 3, Model 6). In the base model, first-time fathers also showed a significantly greater decline in PRL compared to experienced fathers ($p < 0.05$; Fig. 3; Table 3, Model 5), which became a statistical trend in the full model (Table 3, Model 6).

Perceived reflected-appraisal scores predicted a significant difference for change in T from B to P30 in the individual (β: 14.74 ± 7.17 [SE]; $p = 0.047$) and full (β: 17.13 ± 7.58; $p = 0.030$) models. A similar pattern was observed for perceived reflected appraisals predicting change in T from B to P60 (individual model β: 15.06 ± 7.40, $p = 0.049$; full model β: 18.02 ± 7.37, $p = 0.02$). In both cases, men with higher perceived reflected-appraisal scores had a small increase in T from B to P30 and B to P60, on average, and men with lower scores generally had a mild decrease in T over the same time periods. A similar pattern was observed for caregiving identity, which predicted a significant difference for change in T between B and P30 in the base model (β: 11.67 ± 3.67; $p = 0.003$) and the full model (β: 11.59 ± 3.82; $p = 0.004$), with men reporting higher ratings generally experiencing a small increase in T from B to P30 and men with lower ratings tending to show mildly declining T.

Although not significant when considered individually, in the full models for change in CORT between B and P60, fathers without infants experienced a larger decline in CORT compared to fathers of infants (β: −0.01 ± 0.01; $p = 0.018$), and first-time fathers showed less of a decline in CORT relative to experienced fathers (β: 0.01 ± 0.01; $p = 0.022$).

To clarify the finding that first-time and experienced fathers differed in their patterns of PRL change, we evaluated whether they also varied in their hours of caregiving reported on the day of sampling, prior to the intervention, as this could have potentially affected PRL reactivity. For the same reason, we also tested these groups for differences in typical, daily levels of physical care to their young children (defined as < 4 years old). There were no significant differences between first-time and experienced fathers for either comparison (both $p > 0.25$). Finally, perceived reflected-appraisal scores were not correlated with caregiving on the day of sampling ($p > 0.7$), which we hypothesized might have accounted for the relationship between higher perceived reflected-appraisal scores and decreases in PRL during father–child play.

Table 1
Father–child interaction: sample characteristics.

	Mean	SD
Demographic characteristics		
Age (years)	26.62	0.27
Education (highest grade)	10.14	4.44
Currently employed (%)	93.0	–
Urban barangay (%)	59.5	–
Fatherhood characteristics		
Duration of marriage	5.43	2.21
Number of children	2.31	1.02
Years as a father	4.35	2.13
Father of an infant (%)	26.2	–
Age of child in interaction	2.55	0.80
Sex of child in interaction (% female)	43.0	–
Hours of daily paternal care	4.70	2.94
Anthropometric characteristics		
BMI (kg/m^2)	23.69	5.21
Triceps skinfold (mm)	16.67	8.75
Body fat percentage	18.85	5.81

Table 2
Correlations (r) between before interaction (B) hormones and relevant covariates.

	B-T	B-CORT	B-PRL
Highest grade completed	0.13	−0.34*	0.03
Duration of marriage	−0.34*	0.001	−0.16
Age of oldest child	−0.15	0.03	−0.09
Body fat (%)	0.07	−0.41**	−0.05
Self-reported stress (month of sampling)	0.14	0.17	−0.17
Self-reported stress (day of sampling)	0.35*	0.04	0.15
Self-reported sleep quality (day of sampling)	0.02	−0.14	−0.04
Hours of care (day of sampling)	−0.05	−0.001_	−0.07

* $p < 0.05$.
** $p < 0.01$.

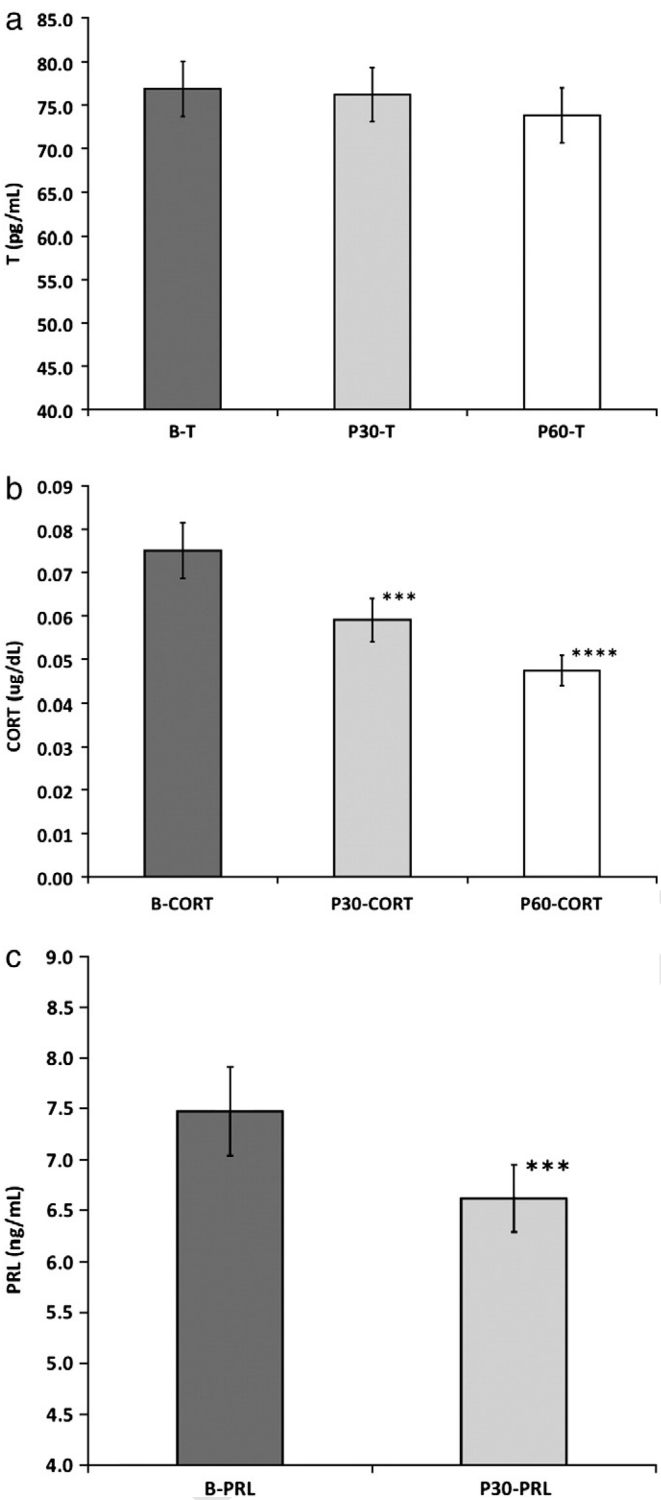

Fig. 1. a–c. B: before interaction, baseline; P30: 30 min after baseline sample; P60: 60 min after initial sample. All hormonal samples adjusted for sampling time and wake time on the day of sampling. ***$p<0.001$, ****$p<0.0001$. Significance indicates differences between P30 and P60 values compared to B values resulting from paired t-tests. Bonferroni correction for multiple comparisons applied to T and CORT, with significance evaluated at $p<0.02$. Error bars indicate s.e.m.

Discussion

In this sample of 26-year-old fathers living in Cebu City, the Philippines, we found that men's CORT and PRL significantly declined during a 30-minute father–child interaction, whereas T did not change. Consistent with previous findings (Delahunty et al., 2007), our results show that paternal experience impacts how fathers' hormones change when they interact with their children, as first-time fathers' PRL declined more over the study period than did the PRL of experienced fathers. We also found that fathers who were more involved in day-to-day caregiving tended to have greater short-term declines in PRL after playing with their child compared to fathers who participated less in routine childcare. In addition, our findings are the first to demonstrate that a father's perceived reflected-appraisals, or his perceptions of how his wife evaluates his performance as a caregiver, have significant implications for paternal hormonal responses to childcare. Specifically, men who thought their wives had a more positive opinion of them as caregivers experienced a greater drop in PRL when interacting with their children compared to men who thought their spouses viewed them less positively. Together, these findings reveal that the Filipino young adult fathers in our sample experienced changes in hormones after interacting with their children and that both the direction and magnitude of these changes were dependent upon other paternal and relationship characteristics.

Because T may conflict with effective parenting in males (Gettler, 2010; Gray et al., 2002; Hau, 2007; Wingfield et al., 1990), we hypothesized that T would decrease after men interacted with their children but found that T did not change among these fathers across the study period. Our findings that fathers' T generally fluctuated very little after interacting with their child are analogous to the results of the only prior similar studies of which we are aware (Gray et al., 2007; Storey et al., in press).

Consistent with our expectations, CORT significantly decreased in men after interacting with their children. This finding is consonant with the results of a recent study conducted in a different cultural context in which fathers' CORT also declined after 30 min of father–toddler interaction (Storey et al., in press). In our sample, experienced fathers showed more of a decline in CORT compared to first-time fathers, though both groups had substantial decreases from baseline (median changes, respectively: −42% and −16%). On the surface, these results might seem to conflict with the expectation that CORT could serve a similar role in mothers and fathers, as studies of human mothers have found that mothers with higher CORT post-partum were more attracted to and affectionate towards their infants (Fleming et al., 1987; Fleming et al., 1997). However, elsewhere it has been shown that mothers with lower CORT participate in more synchronous and reciprocal interactions with their husbands and children, likely reflecting familial cohesion (Gordon et al., 2010a) and that maternal CORT acutely decreased after infant holding (Heinrichs et al., 2001; Mörelius et al., 2005). The observed decrease in CORT in our sample could have been driven by increased oxytocin, which has been shown to reduce pituitary production of adrenocorticotropin (ACTH), leading to lower CORT in men (Legros et al., 1984; Page et al., 1990). A recent study by Feldman et al. (2010) found that fathers who engaged in more tactile play with their children had greater oxytocin 15 min later compared to men less involved in such play, and that fathers with higher oxytocin also direct more affectionate behavior towards their spouse and children (Gordon et al., 2010a).

Based upon the well-described role of PRL in facilitating maternal behavior in mammals and paternal behavior in birds (Numan and Insel, 2003; Ziegler, 2000), we predicted that fathers' PRL would increase as a result of father–child play. Contrary to our expectations, men's PRL substantially decreased over the study period, with first-time fathers showing more of a decline in PRL compared to men with more than 1 child. In contrast to our findings, previous studies have shown that experienced fathers exhibit an increase in PRL in response to hearing infant cries (Delahunty et al., 2007; Fleming et al., 2002), although, similar to our results, a recent study of first-time fathers also found a decrease in PRL after men interacted with their toddlers (Storey et al., in press). One possible explanation for these discrepancies across studies is that listening to infant cries is stressful whereas playing with a child is more pleasurable, thus involving

Table 3
Q8 Predicting ΔPRL: before interaction (baseline) to 30 min later[a].

	Model 1	p	Model 2	p	Model 3	p	Model 4	p	Model 5	p	Model 6	p
Hours of daily care	**−0.13 ± 0.06**	**0.03**									−0.08 ± 0.06	0.16
Caregiving identity			−0.46 ± 0.31	0.15							–	–
Perceived reflected appraisals					**−1.61 ± 0.53**	**0.004**					**−1.26 ± 0.54**	**0.03**
Fathers without an infant[b]							−0.36 ± 0.40	0.38			−0.12 ± 0.38	0.75
First-time father[c]									**−0.82 ± 0.38**	**0.04**	−0.65 ± 0.37	0.09
Model adjusted *R*2	0.074		0.007		0.151		−0.028		0.063		0.217	

[a] Values are β ± SE of partialed ΔPRL (see Methods). Models adjusted for duration of father–child interaction.
[b] Excluded comparison group: fathers with an infant-aged (1 year old or less) child.
[c] Excluded comparison group: fathers with 2 or more children.

different physiological reactions. It has been proposed that first-time and experienced fathers may vary in their patterns of PRL reactions to child contact because they differ in the amount of care they provide to their infant-aged children prior to sampling (Delahunty et al., 2007), and paternal care in the hours before father–child interaction has been shown to affect PRL reactivity among first-time fathers (Storey et al., in press). In our sample, fathers with an infant did not differ in their pattern of PRL change relative to fathers without infants. Moreover, first-time and experienced fathers did not vary in hours of caregiving on the day of sampling or amounts of day-to-day caregiving time directed at men's youngest children, suggesting that this hypothesis does not apply to our sample.

Men who believed that their wives had a more positive view of them as caregivers (perceived reflected-appraisals) also showed a greater decline in PRL relative to men who perceived less positive spousal evaluations. Because men who thought their wives viewed them positively were more involved in day-to-day childcare (Gettler, n.d.), it seemed plausible that these men might have participated in more care on the day of sampling, leading to a difference in PRL reactivity during the intervention (Delahunty et al., 2007; Storey et al., in press). Contrary to this expectation, men with higher perceived reflected-appraisal scores did not report being more involved with childcare on the day of the interview, prior to sampling.

Why PRL decreased during father–child interaction in most of the men in our study is unclear. Past studies found that PRL decreased within 30–60 min after men took drugs that activated dopamine circuits (Mendelson et al., 1992; Mendelson et al., 2003) and that dopamine antagonists' occupation of dopamine receptors resulted in dose-dependent elevations of PRL (Schlegel et al., 1996; Turrone et al., 2002). Hence, to the extent that first-time fathers may have experienced father–child play as more novel/rewarding compared to experienced fathers and because first-time fathers may generally be more sensitive to dopamine-mediated reinforcement of parenting behaviors, the regulation of PRL by dopamine may help explain the patterns of change in PRL we observed here (Spanagel and Weiss, 1999). Similarly, men who feel their partners think of them positively as caregivers may also find paternal care to be a more implicitly pleasurable task or may find it more rewarding because of anticipated social capital with their wives, which could reflect mating-effort (see below). This regulatory model suggests that PRL may serve as a peripheral marker of fathers' central dopamine activity. Future research integrating brain imaging of dopamine reward centers and PRL biomarker methods could shed further light on these issues in fathers (Swain et al., 2007).

Views on paternal care in this sample seem to represent a departure from traditional models of fatherhood in the Philippines that emphasized the father's role as a breadwinner (Gettler, n.d.; Medina, 2001). Specifically, in response to being asked how the role of fathers has changed since their childhood, multiple respondents communicated that their own fathers were uninvolved and emotionally distant during their childhood, whereas today's fathers can and should share caregiving responsibilities with mothers (Gettler, n.d.). Consequently, the level of paternal care we documented here (mean: 4.7 h per day) seems unsurprising and is consistent with other reports of increasing paternal involvement in the Philippines (Harper, 2010; Medina, 2001; Tan, 1997). However, mothers are still generally identified as

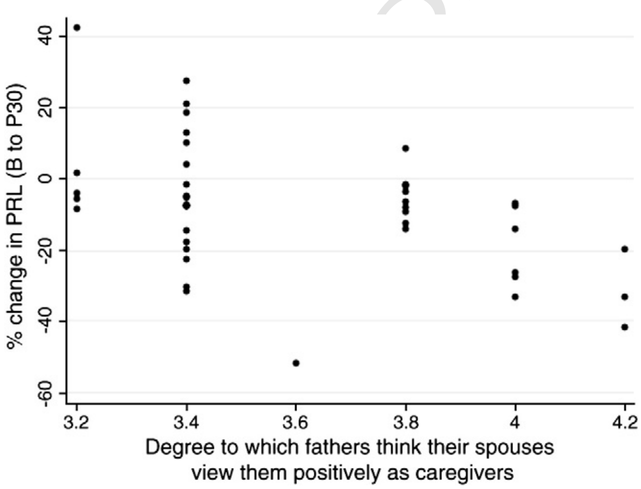

Fig. 2. Scatter plot of % change in PRL, adjusted for sampling time and wake time on the day of sampling, between B and P30 graphed over perceived reflected-appraisal scale (PRA) scores. B: before interaction, baseline; P30: 30 min after baseline sample. Men with higher PRA scores show significantly greater decline in PRL relative to men with lower PRA. See Table 3 for full results and statistical models.

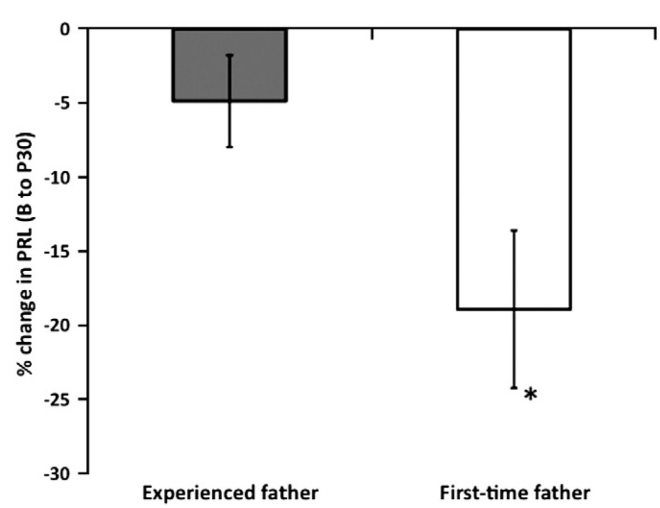

Fig. 3. B: before interaction, baseline; P30: 30 min after baseline sample. First-time father: man with 1 child (n = 11); Experienced father: man with 2 or more children (n = 31). % change in PRL, adjusted for sampling time and wake time on the day of sampling, between B and P30 graphed over paternal experience. First-time fathers show significantly greater decline in PRL relative to experienced fathers. See Table 3 for full results and statistical models. *p < 0.05. Error bars indicate s.e.m.

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the primary child caregivers in the Philippines (Medina, 2001), and it is probable that mothers act as "gatekeepers" to childcare by determining the extent of paternal involvement (McBride et al., 2005). Consistent with this notion, men who perceived that their wives thought highly of them as caregivers tended to participate in more daily childcare (Gettler, n.d.) and showed more hormonal responsiveness to father–child play, perhaps reflecting a psychobiological manifestation of maternal influence. It is also plausible that males who thought their wives viewed their caregiving abilities positively were better caregivers as a means to gain standing with their wives, a form of "mating effort," though results to the contrary have been documented elsewhere (Winking et al., 2009). In our sample, the men's spouses agreed (49%) or strongly agreed (51%) that their husbands' main reason for participating in childcare was to help them, lending credence to the possibility that male hormonal responsiveness related to perceived reflected-appraisals may be mating-related.

This study is limited by having hormonal data from a single home visit and father–child interaction. Had it been feasible, multiple hormonal measures from the same men, taken over multiple home visits would likely have increased reliability (Dabbs, 1990), though previous studies on short-term changes in paternal hormones have also used single visit hormonal measurements (Delahunty et al., 2007; Feldman et al., 2010; Gray et al., 2007; Storey et al., 2000). Moreover, a father–toddler interaction study with comparable results to ours used repeat sampling and documented similar patterns of change for PRL, CORT, and T in both home visits (Storey et al., in press). Although only 4 men in our sample reported feeling that the father–child interaction was stressful and our regression analyses partialed out the effects of baseline values on patterns of hormonal change, it is plausible that the results we documented here represent unmeasured reactions to the study design. For example, in a recent study, men were found to exhibit short-term (~20 min) elevations in PRL in response to experimentally imposed psychosocial stress, which then attenuated shortly thereafter (Lennartsson and Jonsdottir, in press). If baseline PRL and CORT were elevated as a consequence of psychosocial stress, this could explain the observed short-term declines in our study. To reduce the influence of stress, we naturalized the men's experience as much as possible by conducting the study in their homes rather than in a laboratory. In addition, the men in this sample have been enrolled in the CLHNS from birth and were familiar with the interview and hormonal collection procedures, making it less likely that the documented patterns were merely reactions to the home visit. Given these factors and the publication of similar results in a study of fathers from a different cultural context (Storey et al., in press), we think it unlikely that our findings owe specifically to stress effects, though we cannot fully rule out this possibility.

In sum, we showed that fathers' CORT and PRL decreased after they played with their children over a 30-minute period. We found a greater decline in PRL in first-time fathers compared to fathers with multiple children. Men who perceived that their partners evaluated them more positively as caregivers also showed more pronounced declines in PRL during the intervention compared to men who perceived less positive evaluations from their spouses, suggesting a psychobiological connection between men's conceptions of themselves as fathers and their hormonal responses to caregiving. These findings indicate that men's neuroendocrine architecture may be attuned to stimuli experienced during father–child contact, which is consistent with a growing body of evidence that human male reproductive physiology is adaptively responsive to fatherhood and participation in childcare.

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