



High paternal testosterone may protect against postpartum depressive symptoms in fathers, but confer risk to mothers and children

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ABSTRACT

Following the birth of an infant, decreases in testosterone and increases in depressive symptoms have been observed in fathers. Paternal testosterone may reflect fathers' investment in pair-bonding and paternal caregiving and, as such, may be associated with maternal and familial well-being. This study tests associations between paternal testosterone, paternal and maternal postpartum depressive symptoms, and subsequent family functioning.

Within 149 couples, fathers provided testosterone samples when infants were approximately nine months old and both parents reported on postpartum depressive symptoms at two, nine, and 15 months postpartum. Fathers with lower aggregate testosterone reported more depressive symptoms at two and nine months postpartum. Mothers whose partners had higher evening testosterone reported more depressive symptoms at nine and 15 months postpartum. Maternal relationship satisfaction mediated this effect, such that mothers with higher testosterone partners reported more relationship dissatisfaction, which in turn predicted more maternal depressive symptoms. Higher paternal testosterone and paternal depressive symptoms at nine months postpartum each independently predicted greater fathering stress at 15 months postpartum. Higher paternal testosterone also predicted more mother-reported intimate partner aggression at 15 months postpartum. In addition to linear relationships between testosterone and depression, curvilinear relationships emerged such that fathers with both low and high testosterone at nine months postpartum reported more subsequent (15-month) depressive symptoms and fathering stress.

In conclusion, whereas higher paternal testosterone may protect against paternal depression, it contributed to maternal distress and suboptimal family outcomes in our sample. Interventions that supplement or alter men's testosterone may have unintended consequences for family well-being.

1. Introduction

The transition to parenthood is marked by a series of dramatic hormonal and neural changes that may facilitate parental adaptation to caregiving. Biopsychosocial mechanisms of postpartum changes in mood and behavior have been primarily investigated in mothers. However, there is intriguing evidence that both animal and human fathers show dynamic changes in hormones in early parenthood (Saltzman and Ziegler, 2014). Testosterone, a steroid hormone from the androgen group that stimulates the development of male secondary sex characteristics, appears to show parenting-related declines among

human and animal fathers (Gettler et al., 2011).

Men's depressive symptoms increase during the early years of parenthood, with evidence that new fathers report depressive symptoms at higher rates than men in the general population (Garfield et al., 2014; Gettler and Oka, 2016; Paulson and Bazemore, 2010). Men's postpartum depression can affect the well-being of mothers and children, so understanding the causes of paternal mood disorders is important not just to father but to family mental health (Ramchandani et al., 2005). It has been theorized that low paternal testosterone may contribute to paternal depressive symptoms following the birth of a child (Kim and Swain, 2007), but no empirical studies have yet tested associations

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between paternal testosterone and postpartum depression.

1.1. Testosterone and depressive symptoms in men

Low testosterone has been identified as a risk factor for depression in men (Vogel et al., 1978), although research findings have been mixed (Amiaz and Seidman, 2008). Several studies have reported higher depression among men with lower testosterone (Almeida et al., 2008; Barrett-Connor et al., 1999; Schweiger et al., 1999) and reductions in depressive symptoms after testosterone supplementation (Zarrouf et al., 2009). However, other investigations have found no associations between men's testosterone and depression (Giltay et al., 2012; O'Connor et al., 2004; Seidman et al., 2001). Testosterone may be most strongly linked with subthreshold depression or dysthymia (Seidman et al., 2002). To date, the literature on testosterone and depression has been limited by a lack of longitudinal research, a constricted age range (with most studies focused on older men), and neglect of contextual variables such as parenting status.

1.2. Testosterone and fatherhood

Biparental mammals including primates, rodents, and humans show significant drops in testosterone during the postpartum period (Saltzman and Ziegler, 2014). Both cross-sectional and longitudinal human studies report low or decreasing testosterone in partnered fathers compared to single men. For example, fathers of young children have significantly lower testosterone levels than similarly-aged males who are not fathers (Berg and Wynne-Edwards, 2001; Gray et al., 2006). Testosterone appears to decline over time among partnered men who become fathers, and steeper declines have been associated with greater childcare involvement (Gettler et al., 2011).

From an evolutionary perspective, lowered testosterone in fathers may reflect a shift away from pursuing new mating opportunities and towards investment in the family (van Anders et al., 2012). Animal studies have linked lower testosterone levels with reduced aggression towards conspecific infants and more time caring for offspring (Clark and Galef, 2000; Perrigo et al., 1991). Consistent with this, men's prenatal and postpartum decreases in testosterone have been associated with sensitive caregiving, as well as greater commitment to the partner relationship (Fleming et al., 2002; Gettler et al., 2011; Storey and Ziegler, 2016). For example, men whose testosterone decreased more over the course of their partner's pregnancy subsequently reported greater postpartum investment in the relationship with the child's mother (Saxbe et al., 2016). Similarly, married men with lower evening testosterone reported greater spousal investment (Gray et al., 2002). In summary, men in early parenthood appear to have lower testosterone levels than at other periods in the lifespan, and this lowered testosterone may reflect fathers' involvement with the family.

1.3. Research integrating testosterone, depression, and family status

Only a few researchers have considered testosterone and depression in conjunction with life history variables. Booth et al. (1999) noted that, while, low testosterone has been implicated in men's depression, high testosterone in males has also been associated with known risk factors for depression, such as aggression, antisocial behavior, and being unmarried or divorced. Within a sample of male veterans, they found a curvilinear relationship between depression and testosterone, such that symptoms were higher at both low and high levels of testosterone. However, after controlling for antisocial behavior, marital status, and employment, high testosterone was no longer associated with depression. This finding supports a "social mediation" model where both low and high testosterone may be problematic and in which high testosterone indirectly affects depression via social and behavioral factors. In another study of couples with school-aged children, neither husband nor wife testosterone was directly associated with marital quality, but

role overload interacted with husbands' testosterone to predict marital quality, such that marital distress was higher among high-testosterone men also reporting greater role overload (Booth et al., 2005). In other words, high testosterone may compromise the partner relationship under stressful life conditions, suggesting again that psychosocial factors may modulate links between testosterone and family outcomes. Similarly, Gettler et al. (2017) found that both low and high levels of a genetic polymorphism linked with testosterone functioning and "androgenicity" predicted relationship instability and low levels of paternal caregiving, although this polymorphism was not associated with paternal depression.

Gettler and Oka (2016) found that men's testosterone interacted with socioeconomic status and relationship and parenting status to predict depression. Within this study, men were identified as fathers if they resided with any children under the age of 18. Low SES, low testosterone, partnered non-fathers had the highest depression rates. Among men living with children, low SES, high testosterone men had mildly elevated depression risk, whereas high SES, high testosterone, partnered men had the lowest depression rates. Partnered men residing with children also had lower testosterone than non-partnered, childless men. Although this is the most comprehensive study of depression, testosterone, and family factors to date, it did not focus specifically on the postpartum period, and men in the sample ranged from 20 to 60 years of age.

No studies have yet examined mothers' depressive symptoms or other aspects of postpartum family functioning in conjunction with fathers' testosterone. Partner social support is known to buffer maternal depression risk during the transition to parenthood (Misri et al., 2000; Stapleton et al., 2012). If fathers with lower testosterone are more invested in the family, higher paternal testosterone might compromise maternal well-being and increase fathers' stress related to parenting. High testosterone in males has also been associated with intimate partner aggression (IPA; McKenry et al., 1995; Pinto et al., 2010). However, the literature on testosterone and IPA has not focused on aggression during the postpartum period (Beydoun et al., 2012).

1.4. Testosterone measurement

Testosterone has a diurnal rhythm, peaking in the morning and declining across the day. Some studies have examined only morning levels (e.g., Almeida et al., 2008; Gray et al., 2006), some only afternoon or evening levels (Fleming et al., 2002; Storey et al., 2000), and some have aggregated both AM and PM measures of testosterone (Giltay et al., 2012). Although many researchers use only morning samples because of testosterone's peak, testosterone sampled later in the day might better reflect exposure to daily social contexts. In a meta-analysis of research on testosterone and aggression, testosterone-behavior relationships were higher for samples taken later in the day (Book et al., 2001). Similarly, Gray et al. (2002) found that evening, but not morning, testosterone levels were associated with relationship and parenting status in men. Collecting multiple measures of testosterone across the day may help elucidate which sampling timepoints best reflect psychosocial processes.

1.5. Current study

The current study examines salivary testosterone levels in fathers, sampled three times over one day, approximately nine months after the birth of their child. We also measured depressive symptoms reported by both parents at three timepoints during the 18 months after birth (approximately two months, nine months, and 15 months postpartum) and assessed fathering stress and mother-reported intimate partner aggression at 15 months postpartum. Our design allowed us to test both cross-sectional relationships (testosterone and depression measured at the same timepoint) as well as longitudinal relationships (whether testosterone predicts depressive symptoms and other outcomes at the

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