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Interplay between oxytocin and testosterone hormonal shift during fatherhood: A review article

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Abstract

The interplay between oxytocin and testosterone level depicted a considerable evidences that to use as background to examine the behavioral adaptations of male during the perinatal period. Oxytocin is evident as bonding hormone is the important for fostering social connection, responsiveness, and fostering behaviors while testosterone is usually associated with effectiveness, supremacy, and aggression. It has been revealed that the hormonal swing in men during their partner's pregnancy and postnatal period suggested rise in oxytocin is linked with lower testosterone level. These changes likely to bring the caregiving behaviors, diminish aggression, and improve emotional connections with the newborn, presenting an evolutionary approach for cooperative parenting. Present review synthesizes endocrinology, anthropology, and psychology findings to explore the mechanisms driving these changes, their behavioral outcomes, and their implications for fatherhood. Furthermore, the article investigates, how these hormonal shifts shape paternal caregiving and influence family dynamics and compare them to similar arrangements in other species. By exploratory biological and societal dimensions, this work provides all-inclusive impression of the hormonal fundamentals of paternal behavior and neural shift during fatherhood.

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Introduction

In all mammalian species, the steroid testosterone (T) and neuropeptide oxytocin (OT) enable psycho-physiological changes necessary for the establishment of parental care (Ziegler and Snowdon, 2000). Mothers are frequently linked to hormonal changes during pregnancy and the postpartum period, but there is mounting evidence that men also experience significant hormonal changes (Gettler *et al.*, 2011).

Oxytocin has been linked to sensitive fathering responses in both humans and animals, and it initiates and modulates parental behavior in many species (Horrell *et al.*, 2021). The interaction between oxytocin and testosterone has become a crucial area of scientific study among these hormonal changes (Feldman, 2015; Gordon *et al.*, 2017). Oxytocin, bonding hormone is a neuropeptide released by the posterior pituitary gland played important role in social bonding, trust and caregiving behaviors (Feldman, 2015; Carter, 2014).

In the perspective of parenting, oxytocin enriches a father's ability to form emotional relations with their child, promoting nurturing and caring behaviors (Gordon *et al.*, 2017). The distinct behavioral collection that characterizes human maternal and paternal care has been allied with oxytocin (Gordon *et al.*, 2010). During interactions, oxytocin is linked to more affectionate touch and social gaze in mothers, whereas it is linked to greater pleasant arousal and stimulation in fathers (Feldman *et al.*, 2010). Peripheral oxytocin levels in human plasma and saliva have been linked to early parenting behaviors, such as how mothers and fathers provide care (Gordon *et al.*, 2011). Positive paternal behavior in human fathers was associated with a decrease in testosterone throughout the transition to motherhood (Perini *et al.*, 2012; Fleming *et al.*, 2002). Compared to men with higher testosterone levels, those with lower testosterone levels showed more empathy and a greater desire to react to their baby's cries (Fleming *et al.*, 2002). The trade-off between mating and parenting has been proposed to be supported by testosterone variations in males throughout the transition to fatherhood (Gettler *et al.*, 2011; Gettler *et al.*, 2013).

However, during the perinatal period, fathers experience a measurable decline in testosterone levels, which is hypothesized to reduce aggressive tendencies and prioritize caregiving (Feldman and Bakermans-Kranenburg, 2017).

Furthermore, males with greater testosterone levels show less emotional touch toward their infant, express less sympathy when the newborn cries for unknown reasons (Fleming *et al.*, 2002; Weisman *et al.*, 2014), and are not as much involved in maternal care (Mascaro *et al.*, 2013), which may reflect declined empathic rejoining to children's needs. Oxytocin is also complex in responsiveness and passion processing (Bartz *et al.*, 2011). The perceived inverse association between oxytocin and testosterone hormones during fatherhood proposes a biologically embedded mechanism aimed at recalibrating male behaviors to nurture family cohesion and effective parenting (Feldman, 2015). Hormonal regulation not only plays important role in paternal caregiving but also agreements valuable insights into broader social and evolutionary contexts (Feldman, 2015; Gordon *et al.*, 2017). The present review article summarized the hormonal shifting and neural adaptations in the Brain during fatherhood.

Materials and methods

Strategy of article selection

This review paper examines the hormonal interactions between oxytocin and testosterone during parenting by thoroughly examining peer-reviewed literature. Three significant scientific databases—Web of Science, PubMed, and Scopus—were searched for relevant literature. Relevant papers were retrieved by using keywords like "oxytocin," "testosterone," "fatherhood," "hormonal changes," "paternal caregiving," and "parenting behaviors," both separately and in combination. Only research published between 2000 and 2024 was included in the search to guarantee that the most recent developments were covered. Filters for human

research and Boolean operators (such as AND and OR) were used to improve the results.

Inclusion and exclusion criteria for literature selection

Peer-reviewed research on the relationship between parenthood and oxytocin and testosterone. Research with human subjects, such as observational studies, longitudinal studies, and experimental designs and articles that highlight the behavioral effects of hormone shifts (e.g., bonding, caregiving). Conference abstracts, unpublished research, and non-peer-reviewed publications. Research that solely focuses on mother or non-paternal caregiving, as well as studies that lack quantitative data on oxytocin or testosterone, were excluded.

Data extraction, sources, quality assessment, and analysis

Important details were taken from each chosen study, such as the study population, methodology, hormone measurements, behavioral results, and pertinent conclusions. A comparative analysis was done to find recurring themes and variations in research. Statistical findings, including effect sizes and confidence ranges, were compiled where appropriate to offer a quantitative viewpoint. Every included paper was carefully evaluated for sample size, methodological rigor, and applicability to the review's goals. This methodology was designed to provide a systematic and thorough examination of the hormonal shifts in fathers during the perinatal period, ensuring that the findings are accurate and comprehensive.

Results

Changes in Hormonal Levels

Fathers during the perinatal period, studies revealed that the consistent pattern of hormonal shift suggested relationship between oxytocin and testosterone and their collective influence on paternal behaviors (Fig. 1, Table 1). Multiple studies reported a significant rise in oxytocin levels in fathers during their partner's pregnancy and postpartum period. For instance, Feldman *et al.* in 2010 found that fathers displayed a 20–30% increase in oxytocin concentrations within the first three months postpartum, correlating with enhanced affectionate behaviors such as holding and playing with their infant. One hundred sixty parents (mothers and fathers) were observed longitudinally during the first six months postpartum, and higher oxytocin levels among fathers were noted to engage in more affectionate touch, such as stroking, kissing, and gentle play with their infants (Feldman *et al.*, 2010). A study by Gordon *et al.* (2017) observed the impact of oxytocin on stimulating play and active engagement. Fathers were videotaped during five-minute play sessions with their infants, and salivary oxytocin levels were measured before and after these sessions. The results showed a significant rise in oxytocin levels following physical interactions, indicating that tactile and stimulating play activates oxytocin release. Fathers with higher oxytocin levels exhibited more vigorous and playful interactions, reinforcing the hormone's role in nurturing behaviors (Gordon *et al.*, 2017). A longitudinal study by Gettler *et al.* in 2011 observed a substantial reduction in testosterone levels in new fathers 465 men from pre-fatherhood into the postpartum period, measuring testosterone levels through saliva samples. It was observed that a 34% decrease in testosterone was within the first year after childbirth, with the sharpest decline occurring in the early postpartum months; this reduction is hypothesized to diminish competitive and aggressive tendencies, aligning with caregiving priorities (Gettler *et al.*, 2011).

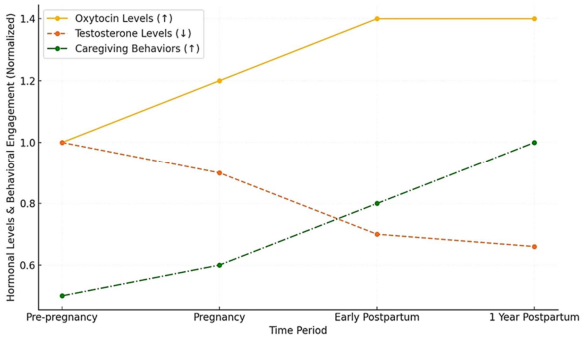

Fig. 1. Demonstration of trend in oxytocin, testosterone, and caregiving behaviors during the prenatal period

Table 1. Hormonal and behavioral changes across studies

Study	Sample size	Oxytocin changes	Testosterone changes	Key behavioral findings
Feldman *et al.* (2011)	160 parents	↑20-30%	↓34%	Enhanced affectionate touch, synchrony
Gordon *et al.* (2017)	80 couples	↑Significant	↓Moderate	Stimulating play, increased engagement
Bakermans- Kranenburg (2017)	152 fathers	↑Significant	↓Significant	Increased reciprocity and touch
Emory Health Sciences (2017)	Brain imaging	↑Neural activity in reward centers	↓None measured	Strengthened bonding through oxytocin-driven reward perception

Bakermans-Kranenburg *et al.* in 2018 examined the interaction between testosterone and oxytocin. Moreover, observed lower testosterone levels and higher oxytocin levels displayed heightened sensitivity and responsiveness toward their infants, and behavioral observations revealed that these fathers were more likely to engage in soothing and protective behaviors, which align with reduced testosterone's role in suppressing aggression (Juffer and Bakermans-Kranenburg, 2018). Lower testosterone levels correlated with decreased engagement in risk-taking and aggressive behaviors, facilitating a more family-focused dynamic (Gettler *et al.*, 2011; Juffer and Bakermans-Kranenburg, 2018). Studies revealed the synergistic effect between oxytocin and testosterone, wherein the balance of these hormones optimized caregiving behaviors while maintaining protective instincts (Juffer and Bakermans-Kranenburg, 2018; Feldman, 2015).

The research highlighted similar hormonal shifts in cooperative caregiving species, such as primates and rodents (Gordon *et al.*, 2017; Feldman *et al.*, 2010; Numan and Woodside, 2010). For example, in marmoset fathers, elevated oxytocin and reduced testosterone levels were linked to heightened engagement in infant care, mirroring the patterns observed in human fathers (Saltzman and Ziegler, 2014). Species to species associations emphasizes the evolutionary significance of the hormonal difference, revealed cooperative parenting may have profound evolutionary roots across species (Gordon *et al.*, 2017; Feldman *et al.*, 2010; Numan and Woodside, 2010). Males' behavioral responses to young frequently undergo significant changes as they enter fatherhood, such as a decrease in hostility toward newborns and an increase in nurturing behavior. Changes in perception, emotion, and thought processes can also be linked to the onset of fatherhood (Horrell *et al.*, 2021). Conversely, reduced hormonal shifts were noted in cultures with less paternal caregiving, such as some patriarchal societies, where caregiving roles are primarily maternal (Gettler *et al.*, 2011; Saltzman and Ziegler, 2014).

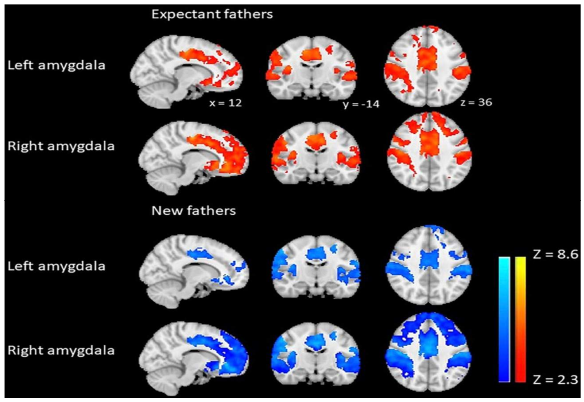

Fig. 2. Right and left amygdala connectivity with parental brain regions in expectant and new fathers. Figure adapted under creative commons attribution non-commercial license (Horstman *et al.*, 2022)

Neural adaptations in the parental brain

A cross-sectional study was conducted by Horstman *et al.* in 2022, involving 131 first-time fathers, divided into two groups such as expectant (62 participants) and new fathers (69 participants) groups. The study analyzed the functional connectivity of the amygdala, a critical region for caregiving and emotional processing, using resting-state functional magnetic resonance imaging (fMRI). Fathers provided data on their involvement in childcare, depressive symptoms,

and demographic factors. By controlling for age, education, and mental health variables, the researchers explored how neural connectivity patterns adapted to caregiving experiences (Fig. 2). Expectant fathers (upper panel, red areas) showed extensive connectivity with brain regions involved in emotional regulation and cognitive processing, while new fathers (lower panel, blue areas) demonstrated reduced connectivity, suggesting focused neural adaptations due to early caregiving experiences (Ahnert *et al.*, 2021).

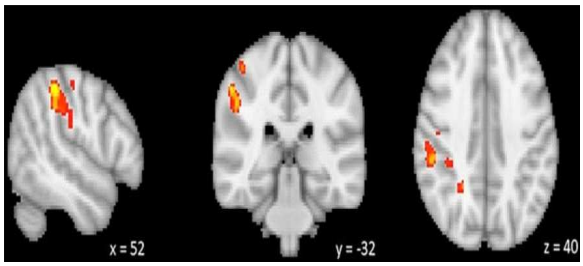

Fig. 3. Association between hours spent in childcare and amygdala connectivity in new fathers. Figure adapted under creative commons attribution non-commercial license (Horstman *et al.*, 2022)

In the same way, a previous study by Feldman *et al.* in 2010 observed heightened amygdala activity in caregiving fathers, similar to maternal brain adaptations observed in earlier studies (Fig. 3). Such adaptations underscore the shared neurobiological mechanisms underlying parental behavior, regardless of gender. Fig. 3 demonstrated correlations between time spent in childcare and right amygdala connectivity with key brain regions. The supramarginal gyrus showed support for empathy and social cognition, the postcentral gyrus showed sensory processing and motor responses essential for caregiving tasks, and the superior parietal lobule showed enhanced attention and spatial processing, helping fathers remain attuned to their infants' needs. In conclusion, the study found that fathers who spent more time in childcare exhibited stronger connectivity between the amygdala, reflecting neural adaptations that support effective caregiving behaviors (Feldman *et al.*, 2010). In the same way, Abraham *et al.* in 2014 demonstrated that fathers involved in direct caregiving exhibit similar neural responses as primary caregiving mothers. The results emphasize that caregiving, rather than biological sex, drives neuroplasticity in the parental Brain (Horstman *et al.*, 2022).

Discussion

In the present review, the article summarized the hormonal and neural systems supporting fatherhood by testing three functional explanations for hormone changes observed when men become fathers. Human social behavior, cognition, and emotion are influenced by the neuroendocrine processes of testosterone and oxytocin, including within the framework of committed social relationships (Rilling, 2013; Storey and Ziegler, 2016). Individuals with elevated testosterone tend to be more oriented toward competition and status-seeking. In contrast, those with lower testosterone are often more nurturant and prosocial, particularly in the context of parenting and partnering (Gray *et al.*, 2017). Increased oxytocin promotes caring and connection, but decreased testosterone probably lessens aggressive and competitive tendencies (Gordon *et al.*, 2017; Kerr and Capaldi, 2019). Additionally, changes in the central and/or peripheral concentrations of several hormones and neuropeptides are linked to the initiation of fatherhood. Fatherhood probably causes additional structural, functional, and neuroendocrine changes in brain regions that both directly and indirectly affect paternal care (Horrell *et al.*, 2021). Hormonal dynamics had significant impact on the mental health during the fatherhood (Gettler *et al.*, 2011; Gordon *et al.*, 2017). The hormonal shifts observed during the perinatal period may influence caregiving and fathers' mental well-being (Gettler *et al.*, 2011; Gordon *et al.*, 2017). Low testosterone levels may make fathers more susceptible to emotional vulnerability, while high oxytocin could mitigate feelings of anxiety and stress (Feldman, 2015; Gordon *et al.*, 2017).

However, these hormonal shifts may also contribute to paternal postpartum depression (PPD), as fathers may experience emotional distress when the oxytocin surge wanes (Gettler *et al.*, 2011).

Perhaps hormonal changes have developed to promote cooperative parenting (Feldman *et al.*, 2010; Numan and Woodside, 2010). These modifications probably promoted more efficient caring, which is essential for the survival of offspring, by lessening aggression and strengthening emotional bonds (Gordon *et al.*, 2017; Saltzman and Ziegler, 2014). Because of this biological adaption, family ties are strengthened, and the child is given the care and protection they require to grow (Feldman, 2015; Abraham *et al.*, 2014). Comparing human fathers to fathers from other species is essential to assess the impact of testosterone on parenting behavior (Feldman, 2015; Numan and Woodside, 2010). The biological consequence of these hormone fluctuations is shown by the similarities observed in marmosets, where higher levels of oxytocin increase caregiving behaviors (Saltzman and Ziegler, 2014). Treatment with intranasal oxytocin changed fathers' physical proximity and movement toward their infants during a play session (Weisman *et al.*, 2012b), and it increased fathers' contact and social reciprocity with their infants (Weisman *et al.*, 2013a) as well Additionally, intranasal occupational therapy increased fathers' sensitivity and reduced their aggression when they played with their kids (Naber *et al.*, 2010; Naber *et al.*, 2013). According to a 2015 study by Mascaro, the drop-in testosterone that comes with becoming a father may be crucial for increasing empathy for kids (Mascaro *et al.*, 2014).

Conclusion

This article focuses on the primary hormonal shifts as the increase in oxytocin and decrease in testosterone among the fathers during his partner pregnancy. These changes bring biologically adaptive development that declines aggression while improving emotional bonding, caregiving, and family interconnection. A perception where concerned activities are prioritized and beneficial for both father and kid is supported by the opposite link between oxytocin and testosterone. Furthermore, by promoting gender parity in caregiving responsibilities and healthy family dynamics, these insights might help shape laws like paternity leave. These results highlight how fathers' brains change dynamically as they take on caregiving responsibilities. The Brain's ability to adjust to the demands of caregiving is reflected in improved amygdala connection with empathic, sensory, and attentional regions. These patterns point to an everyday biological basis for parenting actions and align with maternal brain adaptations. This study proposed strong indication of the experiential and neurobiological features influencing fatherhood by concerning childcare involvement to particular brain circuits. Despite the understanding, research gaps remain. Future studies should examine diverse cultural contexts and the long-term impact of hormonal shifts during fatherhood, and research would provide a more comprehensive understanding of the biological, psychological, and social dimensions of fatherhood.

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