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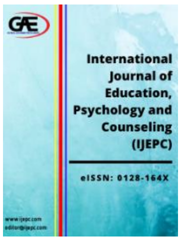

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TESTOSTERONE AND SOCIAL HIERARCHIES: FROM NEURAL MECHANISMS TO BEHAVIOURAL OUTCOMES

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Abstract:

Testosterone is traditionally linked to aggression and dominance, yet growing evidence indicates that its influence on social behaviour is multifaceted. This review synthesizes key findings on testosterone's role in shaping both aggressive and prosocial forms of dominance, drawing from animal and human research. Three cornerstone papers—Watanabe and Yamamoto (2015), Terburg and Van Honk (2013), and Johnson et al. (2012)—provide a foundation for understanding how testosterone interacts with multiple neural circuits, notably the amygdala, prefrontal cortex, and reward systems. These interactions can diminish inhibitory control while heightening reward sensitivity, thereby encouraging approach-oriented behaviours. However, whether elevated testosterone fosters aggression or prosocial leadership depends on contextual and individual factors, including personality traits and cultural norms. Baseline testosterone levels reliably predict discomfort in low-status positions and a drive toward higher social standing. Nevertheless, testosterone's effects are shaped by complex interplays with cortisol,

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vasopressin, dopamine, and serotonin—emphasized by the dual-hormone hypothesis and recent neuroendocrine models. Methodological variations, such as hormone measurement techniques and experimental designs, contribute to conflicting findings in the literature. Recognizing testosterone as a dynamic modulator of social behaviour rather than a unidimensional "aggression hormone" broadens our understanding of human social hierarchies. Future research should employ longitudinal designs, cross-cultural studies, and advanced neuroimaging to unravel how testosterone's nuanced effects can manifest in aggression, assertiveness, or cooperative leadership. This multi-level approach holds promise for improving theoretical models of social hierarchy and informing practical interventions in domains such as organizational leadership and mental health.

Keywords:

Testosterone, Social Dominance, Aggression, Neural Mechanisms, Prosocial Behaviour, Neuroendocrinology

Introduction

Testosterone, a steroid hormone primarily produced in the testes (males) and ovaries (females), plays a pivotal role not only in physiological development but also in shaping social behaviours. While traditionally associated with secondary sexual characteristics and reproduction, contemporary research has increasingly focused on testosterone's influence on social dynamics, particularly dominance, aggression, competition, and prosocial behaviours (Archer, 2006; Eisenegger et al., 2011; Schultheiss & Mehta, 2018). This multifaceted role of testosterone is underscored by its impact on neural circuits, hormonal interactions, and behavioural responses, all of which contribute to the establishment and maintenance of social hierarchies (Geniole & Carré, 2018; Welker, Norman, & Carré, 2021).

Recent advancements in social neuroendocrinology have explored the complex interplay between testosterone and dominance, considering factors such as individual differences, contextual cues, and cultural norms (Zilioli & Bird, 2021). For instance, the dual-hormone hypothesis posits that the combined influence of testosterone and cortisol, a stress hormone, significantly affects dominance behaviours (Mehta & Josephs, 2010). Moreover, research has investigated the impact of testosterone on specific neural circuits, such as the amygdala and prefrontal cortex, further elucidating its role in social cognition and behaviour (Bos et al., 2016; Volman et al., 2021). These findings highlight the need for a comprehensive understanding of testosterone's effects, moving beyond simplistic associations with aggression and considering its broader implications for social interactions.

Recent studies have continued to expand our understanding of testosterone's role in social behaviours. For example, research has shown that higher testosterone levels significantly boost dominance behaviours as individuals climb social hierarchies (Inoue et al., 2024). Additionally, testosterone has been linked to both prosocial and aggressive behaviours, depending on the context and individual differences (Graumann et al., 2025). These insights underscore the hormone's complex role in social dynamics, challenging the traditional view of testosterone as merely a driver of aggression (Hedrih, 2024).

In 2023, a study by Kutlikova et al. demonstrated that exogenous testosterone can eliminate strategic prosocial behaviour, reducing submission to audience expectations and altering decision-making processes (Kutlikova et al., 2023). This finding provides novel evidence of testosterone's effects on implicit reward processing, further highlighting its role in social behaviour.

This narrative review synthesizes key findings from three seminal papers – Watanabe and Yamamoto (2015), Terburg and Van Honk (2013), and Johnson et al. (2012) – and integrates these insights with a broader collection of research, including recent investigations. By examining these diverse perspectives, this review aims to provide a nuanced understanding of testosterone's role in social dominance, considering its potential to promote both aggressive and prosocial behaviours.

Methods

This narrative review was conducted by systematically searching relevant databases (PubMed, PsycINFO, Google Scholar) using keywords such as "testosterone," "social dominance," "aggression," "prosocial behaviour," "neural mechanisms," and "hormonal interactions." The search was limited to articles published in English from 2000 onwards, with a particular focus on studies recent advancements in the field. The initial search yielded over 500 articles, which were then screened based on their titles and abstracts. Full-text articles were retrieved for those deemed relevant, and a final selection of 75 articles was included in this review.

The selected articles were critically evaluated for their methodological rigor, sample size, and relevance to the topic of testosterone and social dominance. Information from these articles was integrated, analysed, and synthesized to provide a comprehensive overview of the current state of knowledge. A table summarizing the key findings of the reviewed literature was created to facilitate understanding and comparison.

To ensure the quality and objectivity of the review, both internal and external peer review processes were employed. Internal peer review involved critical feedback and suggestions from colleagues specializing in social neuroendocrinology. External peer review was conducted by submitting the manuscript to experts in the field for blind review. Feedback from both internal and external reviewers was carefully considered and incorporated into the final version of the manuscript.

Literature Review

Table 1: Summary Table of Key References

Theme	Key References
Defining Social Dominance	Cook et al. (2014), Hall et al. (2005), Henrich & Gil-White (2001), Inoue et al. (2024), Kutlikova et al. (2023), Germar and Mojzisch (2020)
Testosterone and Dominance Behaviours	Watanabe and Yamamoto (2015), Archer (2006), Geniole et al. (2020), Eisenegger et al. (2011), Terburg and Van Honk (2013), Johnson et al. (2012), Hedrih (2024), Graumann et al. (2025), Dakin et al. (2020)

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Aggression vs. Prosociality	Eisenegger et al. (2011), Hamilton & Meston (2018), Welker et al. (2021), Dreher et al. (2016)
Neural Mechanisms: Amygdala	Ledoux (2007), Goetz et al. (2014), Noonan et al. (2014), van Wingen et al. (2010), Reimers & Diekhof (2019), Hermans et al. (2008)
Neural Mechanisms: Reward Circuits	Berridge (2007), Norman et al. (2018), Terburg & Van Honk (2013), Welker et al. (2021), Geniole & Carré (2018), Martinez et al. (2010), Mohebi et al. (2023)
Neural Mechanisms: Prefrontal Cortex	Miller & Cohen (2001), van Wingen et al. (2009), Schultheiss & Mehta (2018), van Wingen et al. (2010), Tyborowska et al. (2024)
Vasopressin and HPA Axis	Donaldson & Young (2008), Wersinger et al. (2007), Macedo et al. (2005), Aikey et al. (2002), Mehta & Josephs (2010), Mehta & Prasad (2015), van Rooij et al. (2021), Szczepanska-Sadowska et al. (2024)
Dopamine, Serotonin, and Cortisol	McGuire & Troisi (1998), Clark & Henderson (2003), Carver et al. (2008), Neurolaunch (2024)
Methodological Variability	Watanabe and Yamamoto (2015), Archer (2006), Geniole & Carré (2018), Zilioli & Bird (2021), Yun et al. (2021)
Contextual Modulation	Terburg and Van Honk (2013), Eisenegger et al. (2011), Dreher et al. (2016), Josephs et al. (2006), Hahn et al. (2021), Rodríguez-Nieto et al. (2021)
Individual Differences	Johnson et al. (2012), Josephs et al. (2006), Carré & Archer (2018), Norman et al. (2018), Leinonen (2023)
Oversimplification of Testosterone	Eisenegger et al. (2011), Hamilton & Meston (2018), Dreher et al. (2016), Welker et al. (2021), Selinger & Thallapureddy (2024)
Multidimensional Model	Schultheiss & Mehta (2018), Zilioli & Bird (2021), Mehta & Josephs (2010), van Rooij et al. (2021), Nickels McLean & Maestripieri (2023), Mohebi et al. (2023), Pfaus (2021), Casto et al. (2023), Harrison et al. (2021), Nepomuceno & Stenstrom (2021)
Cultural and Gender	Dabbs & Morris (1990), Edwards & Casto (2013), Hamilton & Meston (2018), Josephs et al. (2006), van Rooij et al. (2021), Nolan et al. (2023), Cheung et al. (2024)

Defining Social Dominance

Social dominance is a multidimensional construct encompassing various aspects, from observable behaviours (e.g., aggression, resource control) to personality traits (e.g., assertiveness, desire to lead) (Hall et al., 2005; Henrich & Gil-White, 2001). While in non-human animals, dominance hierarchies often rely on physical prowess, human social hierarchies are more complex, influenced by intelligence, emotional intelligence, and cultural factors.

Cook et al. (2014) differentiate between two types of dominance: (1) social dominance, often associated with prosocial behaviour and leadership, and (2) aggressive dominance, characterized by hostility and coercion. Testosterone has been linked to both types, with its

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expression moderated by individual differences, situational cues, and cultural norms (Archer, 2006; Schultheiss & Mehta, 2018). From an evolutionary perspective, testosterone's facilitation of dominant behaviours may have provided reproductive and survival advantages by securing resources and mates (Wingfield et al., 1990). However, the complexity of human social systems necessitates a more nuanced understanding of dominance, recognizing that it is not solely expressed through aggression (Dabbs & Morris, 1990; Reimers & Diekhof, 2019).

Recent studies have further explored these dynamics. For instance, Inoue et al. (2024) found that higher testosterone levels significantly boost dominance behaviours as individuals climb social hierarchies1. Additionally, research by Kutlikova et al. (2023) demonstrated that exogenous testosterone can eliminate strategic prosocial behaviour, reducing submission to audience expectations and altering decision-making processes. Germar and Mojzisch (2020) also found that basal testosterone renders individuals more receptive to minority positions, suggesting a role in social change1. These findings highlight the complex interplay between testosterone and social dominance, challenging traditional views.

Testosterone and Dominance Behaviours

Watanabe and Yamamoto (2015) provide a comprehensive overview of testosterone's influence on dominance behaviours, indicating that individuals with elevated testosterone often engage in behaviours aimed at attaining or reinforcing social status. For example, the "winner effect" demonstrates that men experiencing a surge in testosterone after a competitive victory exhibit increased assertiveness and confidence (Archer, 2006; Geniole, Bird, Ruddick, & Carré, 2020). However, this same mechanism can manifest as hostility or aggression in situations where aggression is perceived as the most effective way to maintain status (Eisenegger et al., 2011).

Terburg and Van Honk (2013) propose that testosterone fosters an approach-oriented mindset, reducing fear and avoidance while increasing the motivation to confront challenges. This can lead to aggression when direct conflict is necessary for acquiring rank, but it can also encourage strategic collaboration when coalition-building is more advantageous (van Honk et al., 2011; Norman et al., 2018; Zilioli & Bird, 2021).

Johnson et al. (2012) emphasize the predictive power of basal testosterone levels for dominance behaviours in both laboratory and real-world settings. Adolescents and young adults with high basal testosterone report more risk-taking and assertive behaviours across various social contexts. Importantly, these individuals often experience discomfort or negative affect when in subordinate positions (Josephs et al., 2006). This discomfort can lead to aggressive displacement or, alternatively, to the development of refined leadership strategies aimed at regaining higher social standing.

Recent research has continued to shed light on these mechanisms. For example, Hedrih (2024) found that testosterone boosts dominance as individuals climb the social ladder, highlighting the hormone's role in social dynamics. Additionally, Graumann et al. (2025) linked elevated testosterone to both prosocial and aggressive behaviours, depending on the context and individual differences3. Dakin et al. (2020) also demonstrated that testosterone-mediated behaviour shapes the emergent properties of social networks, influencing group dynamics and cooperation.

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Aggression Versus Prosociality

While testosterone has long been associated with aggression, recent research reveals its potential to facilitate prosocial or cooperative behaviours, particularly when these behaviours offer a viable path to elevated status (Eisenegger et al., 2011; Hamilton & Meston, 2018; Welker et al., 2021). In contemporary societies, effective leadership often requires empathy, collaboration, and the ability to build and maintain group cohesion. Therefore, elevated testosterone does not necessarily translate into overt aggression; rather, it can amplify motivational salience, driving behaviours aligned with the most effective dominance strategy in a given context (Dreher et al., 2016). This highlights the dynamic interplay between testosterone, individual differences, and situational factors in shaping social behaviour.

Neural Mechanisms Underlying Testosterone's Effects

The Amygdala: Emotional Reactivity

The amygdala, a key brain region for processing emotional and threat-related stimuli (Ledoux, 2007), exhibits heightened reactivity under the influence of testosterone, particularly to cues signaling potential conflict (e.g., anger, fear) (Goetz et al., 2014). This heightened activation primes the individual for decisive responses, ranging from calm assertiveness to overt aggression. Furthermore, studies have identified structural links between amygdala volume and social status in both humans and non-human primates (Noonan et al., 2014).

Exogenous testosterone administration has been shown to reduce functional connectivity between the amygdala and the orbitofrontal cortex (OFC) (van Wingen et al., 2010; Reimers & Diekhof, 2019). This reduced connectivity can weaken inhibitory control over impulsive or aggressive actions (Hermans et al., 2008), a mechanism that may be adaptive in situations requiring swift dominance but less so in cooperative or prosocial settings (Eisenegger et al., 2011; Zilioli & Bird, 2021).

Reward Circuits: Dopamine and Nucleus Accumbens

Testosterone interacts with dopaminergic pathways in the striatum and nucleus accumbens, key components of the brain's reward circuitry (Berridge, 2007; Norman et al., 2018). By enhancing dopamine release or receptor sensitivity, testosterone can increase reward sensitivity, intensifying the motivation to attain or maintain high status (Terburg & Van Honk, 2013; Welker et al., 2021). Laboratory studies suggest that this dopamine-testosterone interplay supports behaviours aimed at achieving recognition, resources, or leadership positions (Geniole & Carré, 2018).

Consistent with this, higher social rank has been correlated with increased dopamine receptor availability (Martinez et al., 2010). Since testosterone upregulates dopaminergic function, individuals with high endogenous testosterone may be more driven to pursue competitive or status-relevant goals. These reward-related effects can fuel both positive leadership qualities (e.g., perseverance, ambition) and negative outcomes if these drives are channelled through antisocial strategies (Dreher et al., 2016; Hahn, Fisher, DeBruine, & Jones, 2021). Recent studies have shown that accumbens cholinergic interneurons dynamically promote dopamine release, further enabling motivation and reward-seeking behaviours (Mohebi et al., 2023).

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Prefrontal Cortex and Inhibitory Control

The prefrontal cortex (PFC), encompassing the OFC and dorsolateral PFC, governs higher-order cognitive functions such as decision-making, planning, and impulse regulation (Miller & Cohen, 2001). Testosterone appears to dampen the PFC's regulatory control over subcortical systems (van Wingen et al., 2009; Schultheiss & Mehta, 2018). For instance, viewing angry faces under testosterone administration reduces functional connectivity between the OFC and amygdala, potentially facilitating rapid or reflexive responses (van Wingen et al., 2010).

While this attenuation of top-down control can predispose individuals to confrontational behaviours, it may also be advantageous in high-pressure situations requiring quick, decisive action (Hermans et al., 2008). However, modern social systems often demand reflective problem-solving and empathy, so testosterone-induced reductions in PFC-amygdala coupling might hinder nuanced social negotiations (Eisenegger et al., 2011; Zilioli & Bird, 2021). Recent research indicates a developmental shift in testosterone's influence on prefrontal emotion control, with varying effects observed from adolescence to adulthood (Tyborowska et al., 2024).

Vasopressin and HPA Axis Interactions

Beyond frontal-limbic pathways, testosterone interacts with vasopressin, a neuropeptide involved in territorial aggression, social bonding, and parental care (Donaldson & Young, 2008). Wersinger et al. (2007) observed that testosterone upregulates vasopressin in the central-medial amygdala (CMA), facilitating aggressive responses, while the basolateral amygdala (BLA) remains less affected (Macedo et al., 2005). This CMA-specific influence highlights the regionally selective nature of testosterone's neural effects.

Testosterone also modulates the hypothalamic-pituitary-adrenal (HPA) axis, often reducing cortisol levels via androgen receptor pathways and GABAergic signalling (Aikey et al., 2002; Schultheiss & Mehta, 2018). According to the "dual-hormone hypothesis" (Mehta & Josephs, 2010; Mehta & Prasad, 2015), high testosterone combined with low cortisol can enhance status-seeking behaviour by reducing anxiety about conflict or punishment. Recent studies support this framework, demonstrating how stress context (e.g., acute stressors vs. stable environments) modulates testosterone's dominance-enhancing effects (van Rooij et al., 2021). Additionally, recent findings highlight the interaction between vasopressin and the HPA axis in regulating stress responses and behaviour (Szczepanska-Sadowska et al., 2024).

Dopamine, Serotonin, and Cortisol Interplay

Finally, testosterone interacts with serotonin and dopamine to shape the broader reward and affective landscape. Chronic social defeat diminishes serotonin function (McGuire & Troisi, 1998), while testosterone administration can restore or enhance it (Clark & Henderson, 2003). Serotonin deficits often correlate with impulsivity or aggression, whereas dopamine's role in reward processing can strengthen status-driven behaviours (Carver et al., 2008). Recent research has further elucidated the complex interplay between testosterone, dopamine, and serotonin, highlighting their combined effects on mood, motivation, and social behaviour (Neurolaunch, 2024). Thus, testosterone orchestrates a delicate hormonal and neurochemical balance, tilting the individual towards approach-oriented actions (Eisenegger et al., 2011; Hamilton & Meston, 2018; Zilioli & Bird, 2021).

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Findings, Comparative Analysis, Evaluation and Key Controversies and Inconsistencies

Methodological Variability

As Watanabe and Yamamoto (2015) note, variability in testosterone research partly stems from methodological differences, including how testosterone is measured (e.g., saliva vs. serum), when it is measured (morning vs. afternoon), and the tasks used to assess dominance. Sample size and demographic factors (e.g., age, sex, cultural background) can further complicate interpretations (Archer, 2006; Geniole & Carré, 2018). Recent efforts emphasize standardized protocols and larger, more diverse cohorts to capture the nuances of hormonal fluctuations over time (Zilioli & Bird, 2021). For example, Yun et al. (2021) recommend performance criteria for testosterone measurements based on biological variation to improve accuracy and reliability.

Contextual Modulation

Terburg and Van Honk (2013) highlight the importance of contextual factors – such as perceived social threat, cultural values, or reward structures – in shaping testosterone's behavioural manifestations. Laboratory studies show that testosterone can promote fair bargaining in economic games if social reputation is at stake (Eisenegger et al., 2011). Conversely, in more competitive or adversarial contexts, elevated testosterone might bolster competitive or even aggressive behaviours (Dreher et al., 2016). Field studies from different cultures suggest that societal norms can either amplify or temper the hormone's expression (Josephs et al., 2006; Hahn et al., 2021). Recent research by Rodríguez-Nieto et al. (2021) underscores the role of individual differences in self-control and testosterone levels in predicting compulsive behaviours.

Individual Differences and Baseline Levels

Johnson et al. (2012) underscore that baseline testosterone levels predict who is most likely to strive for leadership or dominance. Individuals with chronically high testosterone may resist or feel discomfort in low-status roles (Josephs et al., 2006). Personality traits and psychosocial variables (e.g., trait anxiety, empathy, narcissism) often moderate the link between testosterone and behaviour (Carré & Archer, 2018; Norman et al., 2018). For instance, high-anxiety individuals might channel testosterone's arousal effects into defensive aggression, while those with prosocial inclinations use the same arousal to foster constructive leadership. Recent studies have shown that genetically determined testosterone levels can impact health and behaviour, highlighting the complexity of these interactions (Leinonen, 2023).

Meta-analyses suggest that exogenous testosterone does not universally increase aggression relative to placebo (van Honk et al., 2012; Schultheiss & Mehta, 2018). Instead, situational triggers and individual predispositions together shape testosterone's ultimate impact, be it aggression, cooperation, or nuanced leadership (Eisenegger et al., 2011).

Oversimplification of Testosterone's Role

Public perception often oversimplifies testosterone's role, portraying it as a mere "violence hormone." However, research consistently reveals a more flexible role (Eisenegger et al., 2011; Hamilton & Meston, 2018). In many modern contexts, leadership and dominance may require negotiation skills or group cohesion; hence, testosterone can enhance social acuity, as success in these domains boosts status (Dreher et al., 2016; Welker et al., 2021). Focusing solely on aggression fails to capture the hormone's potential to support complex social strategies.

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Instead, multi-factor models integrating neural, endocrine, and cultural variables offer a fuller understanding (Terburg & Van Honk, 2013; Zilioli & Bird, 2021). Recent studies have further explored the nuanced roles of testosterone in social behaviour, challenging the oversimplified view of it as merely a driver of aggression (Selinger & Thallapureddy, 2024).

Table 2: Synthesis of the Three Key Papers

Paper	Strengths	Limitations
Watanabe and Yamamoto (2015)	Provides a comprehensive overview of the neural substrates involved in testosterone's influence on dominance.	Does not delve deeply into how personality or methodological differences can explain contradictory findings.
Terburg and Van Honk (2013)	Proposes an approach-avoidance framework to explain how testosterone influences dominance and aggression.	Could benefit from a deeper analysis of prosocial outcomes and cultural moderators.
Johnson et al. (2012)	Establishes basal testosterone as a robust predictor of dominance behaviours in both laboratory and real-world settings.	Focuses less on detailed neural mechanisms and could benefit from a more comprehensive discussion of contextual factors.

Toward a Multidimensional Model

Recent research (e.g., Schultheiss & Mehta, 2018; Zilioli & Bird, 2021) emphasizes the need for an integrative model that considers:

Dual-Hormone Interactions (Testosterone & Cortisol): Low cortisol can magnify testosterone’s dominance-promoting effects, aligning with the dual-hormone hypothesis (Mehta & Josephs, 2010). Recent studies support this framework, demonstrating how stress context (e.g., acute stressors vs. stable environments) modulates testosterone’s dominance-enhancing effects (van Rooij et al., 2021; Nickels McLean & Maestripieri, 2023).

Neurochemical Substrates (Dopamine & Serotonin): Testosterone’s modulation of reward and affect circuits helps explain individual variability in aggression vs. cooperation. Recent research highlights the role of testosterone in enhancing dopamine release and receptor sensitivity, which can influence reward-seeking behaviours (Mohebi et al., 2023; Pfaus, 2021).

Personality & Psychopathology: Traits like empathy, anxiety, and narcissism can direct testosterone’s approach energy towards constructive or destructive ends (Carré & Archer, 2018; Norman et al., 2018). Recent findings suggest that personality traits and psychosocial variables significantly moderate the link between testosterone and behaviour (Casto et al., 2023; Leinonen, 2023).

Contextual & Cultural Variables: The environment – be it competitive or collaborative – can shift how testosterone-driven motives are enacted (Eisenegger et al., 2011; Hahn et al., 2021). Recent studies indicate that cultural norms and socioeconomic factors play a crucial role in moderating testosterone’s behavioural effects (Harrison et al., 2021; Nepomuceno & Stenstrom, 2021).

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Such frameworks would help unify seemingly disparate findings, explaining when and why testosterone yields different behavioural outcomes.

Cultural and Gender Considerations

One critique of testosterone research is its predominant focus on male samples in Western societies (Dabbs & Morris, 1990). However, evidence suggests that hormonal fluctuations in women, including cyclical changes in testosterone, can also influence assertiveness, competitive drive, and interpersonal dynamics (Edwards & Casto, 2013; Hamilton & Meston, 2018). Additionally, cross-cultural perspectives demonstrate that norms regarding aggression, hierarchy, and cooperation shape whether testosterone fosters direct hostility or nuanced leadership (Josephs et al., 2006; van Rooij et al., 2021). Recent studies have shown that testosterone therapy significantly decreases gender dysphoria, depression, and suicidality in transgender and gender-diverse individuals (Nolan et al., 2023; Cheung et al., 2024). Longitudinal studies might further clarify how life events – such as parenthood or career transitions – alter hormonal profiles and status-related behaviours (Gettler et al., 2011).

Conclusion

This narrative review has provided a comprehensive overview of testosterone's multifaceted role in social dominance, drawing on a wide range of research, including seminal papers and recent investigations. The review has highlighted the complex interplay between testosterone, neural mechanisms, hormonal interactions, individual differences, and contextual factors in shaping dominance behaviours. While testosterone has traditionally been associated with aggression, this review emphasizes its potential to promote both aggressive and prosocial behaviours, depending on a variety of moderating factors.

Limitations

Despite the breadth of research covered, this review has some limitations. First, the majority of studies included focused on male participants, limiting the generalizability of findings to women. Second, most research has been conducted in Western, educated, industrialized, rich, and democratic (WEIRD) societies, potentially overlooking cultural variations in testosterone's effects. Third, the review primarily focused on correlational studies, making it difficult to establish definitive causal relationships between testosterone and social dominance.

Future Directions

Future research should address these limitations by:

- **Including more diverse samples:** This includes increasing representation of women, individuals from non-WEIRD cultures, and diverse age groups.
- **Employing longitudinal designs:** Longitudinal studies can help track the dynamic interplay between testosterone, social experiences, and dominance behaviours over time.
- **Utilizing experimental manipulations:** Experimental studies can help establish causal relationships and investigate the specific mechanisms through which testosterone influences social dominance.
- **Exploring the role of other hormones:** Investigating the interplay between testosterone and other hormones (e.g., oxytocin, vasopressin) can provide a more complete understanding of hormonal influences on social behaviour.

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- **Considering the ethical implications:** As testosterone replacement therapy becomes more prevalent, it is crucial to consider the ethical implications of manipulating testosterone levels and its potential impact on individuals and society.

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