



Exogenous testosterone increases men's perceptions of their own physical dominance



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ABSTRACT

Men's testosterone is associated with several constructs that are linked to dominance rank, such as risk-taking, mating success, and aggression. However, no study has directly tested the relationship between men's self-perceived dominance and testosterone using an experimental design. We employed a within-subjects, double-blind, placebo-controlled paradigm to assess whether testosterone influences men's self-perceived dominance. Exogenous testosterone or a placebo was administered to healthy adult men and self-perceptions of physical dominance were subsequently assessed by having participants select what they believed to be their true face from an array of images digitally manipulated in masculinity. Men picked a more masculine version of their own face after testosterone versus placebo—an effect that was particularly pronounced among men with relatively low baseline testosterone. These findings indicate that a single administration of testosterone can rapidly modulate men's perceptions of their own physical dominance, which may explain links between testosterone and dominance-related behaviors.

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1. Introduction

Across various species, higher concentrations of testosterone are associated with increased mating effort and lower concentrations with increased parenting effort (e.g., McGlothlin et al., 2007). Although testosterone is positively associated with the likelihood of reproducing among men (Jasienska et al., 2012), becoming a father is associated with a drop in circulating testosterone that is mediated by the amount of parental investment (Gettler et al., 2011). Similarly, men in committed relationships have lower testosterone concentrations than single men (e.g., Gray et al., 2002) and testosterone declines over the course of a committed relationship (Gray et al., 2004). Others have found positive relationships between testosterone concentrations and men's mating effort. For instance, sociosexual behaviors, such as the number of previous sexual partners (e.g., Pollet et al., 2011) and the pursuance of polygynous

mating styles (Gray, 2003), are positively correlated with baseline testosterone concentrations. However, one study found that the actual number of sexual partners negatively relates to testosterone when statistically controlling for sociosexual interest, perhaps due to a negative feedback loop (i.e., satisfaction of sexual desires may feed back negatively on testosterone (Puts et al., 2015)). Moreover, competition-induced fluctuations in testosterone concentrations are positively correlated with men's competitive motivation and aggression (reviewed in Carré and Olmstead, 2015), risk-taking (Apicella et al., 2014), and mate-seeking behavior (e.g., van der Meij et al., 2012). These findings are consistent with animal models (e.g., McGlothlin et al., 2007) and suggest that testosterone may mediate trade-offs between mating effort and parenting effort.

It is possible that testosterone influences perception of one's own dominance, which in turn potentiates subsequent mating effort. Some evidence suggests individual differences in self-report trait dominance are positively correlated with testosterone concentrations (Carré et al., 2009; Sellers et al., 2007; Stanton and Schultheiss, 2009; Turan et al., 2014). Also, self-reported dominance is associated with sensitivity to cues of dominance from others. Specifically, men scoring relatively low versus high in trait dominance are more sensitive to dominance cues in other men's faces (e.g., Watkins et al., 2010a but see Wolff and Puts, 2010),

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presumably because men lower in dominance are at higher risk of debilitating injury or loss of other resources resulting from within-sex competition (discussed in [Watkins et al., 2010a](#); [Watkins and Jones, 2012](#)). One inherent limitation of these studies is that they employed trait-based measures of dominance and testosterone, whereas both dominance and testosterone concentrations are not static, but rather fluctuate in response to competitive social interactions. Indeed, acute fluctuations in dominance status influence social perception, neuroendocrine function, and aggressive behavior—all factors that play a key role in processes related to mating effort. For instance, [Watkins and Jones \(2012\)](#) experimentally primed men to imagine winning or losing confrontations with other men and found that men who imagined losing against other men showed greater sensitivity to the dominance of other men's faces than did men who imagined winning against other men. Moreover, compared to losers, winners of a competitive interaction are more aggressive toward an intra-sexual rival—an effect that is mediated by enhanced testosterone concentrations in winners ([Carré et al., 2013](#)). Given that men's dominance sensitivity fluctuates as a function of priming win/loss outcomes ([Watkins and Jones, 2012](#)) and that rapid increases in testosterone for the victors of competitive interactions may influence subsequent aggression ([Carré et al., 2013](#)), it is possible that testosterone influences men's perceptions of their own and/or others' dominance.

In humans, perceptions of dominance are made very quickly ([Carré et al., 2009](#)), are fundamental to how we evaluate others ([Keating and Bai, 1986](#); [Oosterhof and Todorov, 2008](#); [Thomsen et al., 2011](#)), and may help reduce the costs of within-sex competition ([Puts, 2010](#)). Here, using a novel implicit measure of self-perceived dominance, we examined the extent to which administration of testosterone modulates men's perception of their own physical masculinity. Because men's facial masculinity is positively related to their physical strength ([Fink et al., 2007](#)), social status ([Mueller and Mazur, 1996](#)), and third-party perceptions of their dominance ([Boothroyd et al., 2007](#); [Perrett et al., 1998](#) see also [Oosterhof and Todorov, 2008](#)), stimuli were systematically manipulated in facial masculinity of 2D face shape. We predicted that testosterone administration would cause men to perceive themselves as more masculine (i.e., more physically dominant). Moreover, given the enormous amount of variability in testosterone concentrations in young men (e.g., [Zitzmann and Nieschlag, 2001](#)), we investigated the extent to which this relationship would be moderated by baseline concentrations of testosterone. A previous meta-analysis found that the effects of testosterone on erectile function and, to a lesser extent, libido depend on basal testosterone concentrations ([Isidori et al., 2005](#)). Specifically, positive effects of exogenous testosterone on these parameters are found exclusively in men with relatively low testosterone concentrations. Although this meta-analysis specifically investigated the relationship between exogenous testosterone and sexual function, it suggests that researchers should consider the potential role of basal neuroendocrine status in moderating effects of testosterone on behavioral outcomes.

2. Material and methods

2.1. Participants

Participants ($M_{\text{age}} = 21.27$ years, $SD = 2.16$, range = 18–28) were 30 healthy adult men who were part of a larger testosterone administration protocol. The sample consisted mostly of heterosexual (1 = homosexual, 1 = other) Caucasian men (1 = First Nations/Aboriginal, 1 = Hispanic), 60% of whom reported currently being in a romantic relationship. Participants were recruited from common areas at an eastern Canadian university via poster adver-

tisements, the online research participant pool, and via e-mail contact with previous participants who consented to offers for participation in future studies. Participant remuneration consisted of \$25 per hour, and partial course credit on day 1 of testing at the course professor's discretion. Men were not eligible if they were currently taking oral, injectable, or transdermal steroid hormones. Also, participants were ineligible if they reported a current diagnosis of a psychiatric disorder (e.g., depression, schizophrenia, alcohol/drug dependence), a diagnosed heart condition, or involvement in any sports team where testosterone is a banned substance. The study was approved by the appropriate university Research Ethics Board and was carried out in accordance with the provisions of the World Medical Association Declaration of Helsinki. Each participant provided informed consent prior to participation. Sample size was in line with previous research (reviewed in [Bos et al., 2012](#)) and was determined prior to data collection.

2.2. Stimuli

Sexually dimorphic traits are physical differences between the sexes (i.e., masculine traits in men and feminine traits in women), whereby more sexually dimorphic individuals are more sex-typical in their physical features. Following established methods (e.g., [Welling et al., 2007, 2008, 2013](#)), prototype-based image transformations were used to objectively manipulate the sexually dimorphic characteristics of 2D digital face images. First, male and female prototype (i.e., average) images were created by averaging the shape, color, and texture of 60 young adult male faces and 60 young adult female faces. Next, we created 10 different versions of each participant's face, whereby each version varied in masculinity/femininity in 15% increments from 75% more feminine to 75% more masculine (see [Fig. 1](#)). Images were made more feminine or masculine by taking a percentage of the linear differences in 2D shape between symmetrized versions of the male and female prototype faces and adding or subtracting them from corresponding points on the participants' original face images (for technical details, see [Tiddeman et al., 2001](#)). Previous research has found that these methods affect perceptions of sexual dimorphism and dominance in the predicted way (e.g., [Watkins et al., 2010b](#); [Welling et al., 2007](#)). This process left us with 11 versions (including the original image) of each participant's face.

2.3. Procedure

Participants completed an introductory session where eligibility was assessed, consent was obtained, and facial photographs were taken. They completed various questionnaires within this session in order to measure constructs to be included as covariates in analyses, including a demographics survey (age, height, weight, lifetime number of sexual partners, relationship status, ethnicity), the Sociosexual Orientation Inventory–Revised (SOI-R; [Penke and Asendorpf, 2008](#)), and the Buss-Perry Aggression Questionnaire ([Buss and Perry, 1992](#)). Participants also provided hand scans for digit ratio analysis during the introductory session. Briefly, 2D:4D ratios were measured by two research assistants from scans of the left and right hands and lengths of the second and fourth digits were computed by measuring the distance between the ventral proximal creases of the digits to the fingertips using ImageJ software (data reported elsewhere; see [Carré et al., 2015](#)). After the introductory session, participation took place over 2 subsequent sessions: one experimental session where participants were administered 150 mg of testosterone, and one control session where participants were administered placebo—both administered by the same male research assistant who was blinded to the treatment condition. Participants completed the Self-Report Psychopathy–Short Form ([Paulhus et al., 2015](#)) at the experimental and control sessions to

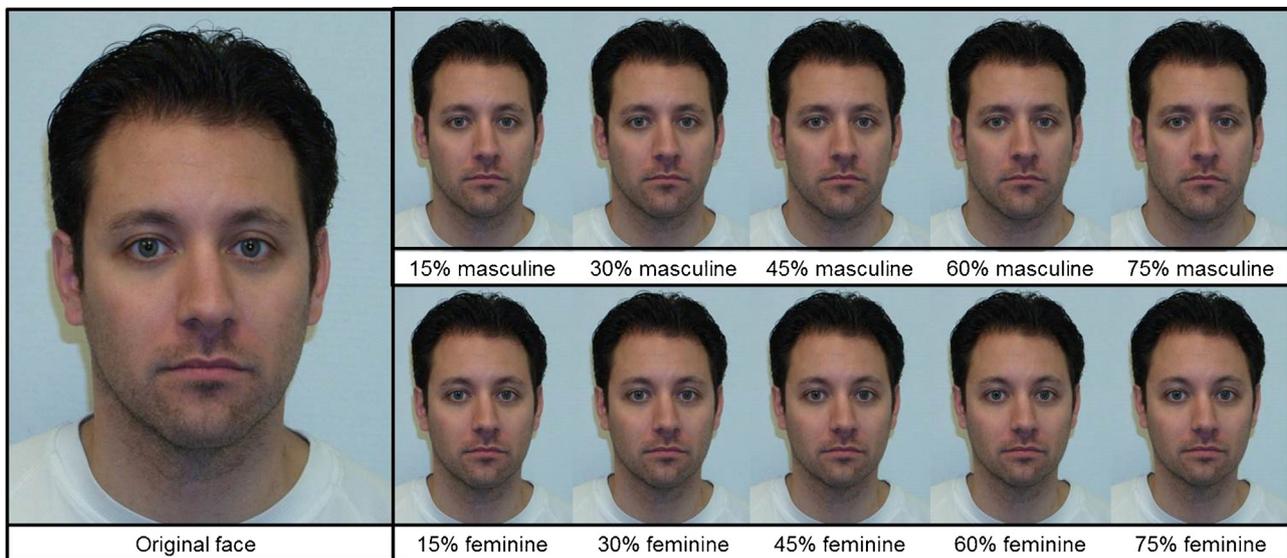


Fig. 1. An original face (left) and examples of masculinized (top row) and feminized (bottom row) versions. Only sexual dimorphism of 2D shape was altered and all other cues (i.e., skin color, texture, and identity) remained constant.

assess variability in psychopathic traits, but this data is reported elsewhere (see Carré et al., 2015). To minimize the potential impact of diurnal hormone fluctuations (e.g., Brambilla et al., 2009), both the experimental and control test sessions took place at the same time of day and always between the hours of 11 am and 5 pm.

Using a double-blind, placebo-controlled, within-subjects design, the experimental and control sessions were identical except for the drug administered (testosterone or placebo). First, a registered nurse drew 10 mL of blood to assay baseline testosterone concentrations. Next, as per Eisenegger et al. (2013) (see also Goetz et al., 2014), participants received either AndroGel® containing 150 mg of testosterone or placebo. Participants provided two additional blood samples at 1 and 2 h post-administration in order to verify change in testosterone concentrations. The order of experimental versus control sessions was counterbalanced across participants and test sessions were spaced 2 weeks apart.

After the final blood sample was taken (2 h post administration), participants were escorted into the laboratory where they performed a series of tasks assessing social perception, cognition, and decision-making abilities at private computer workstations (see supplemental analyses below; see also Carré et al., 2015). Finally, participants completed a novel pick-your-own-face task. Half of the participants completed this task approximately 2 h and 20 min after receiving testosterone/placebo ($M = 144$ min, $SD = 6$ min) and the other half completed this task approximately 4 h after testosterone/placebo ($M = 241$ min, $SD = 9$ min). The rationale for looking at both time points was that time course for the behavioral effects of testosterone is not known in young men, and thus, we wanted to see whether testosterone would exert relatively rapid and/or delayed effects on self-perception of dominance.¹ For this task, participants had to select which of several face images they believed was their real face. They were given the following instructions:

Next, you will see several pictures of yourself. Each photograph looks very similar, but is subtly different. Please choose the face you think is most likely to be your real (original) photograph by clicking on the appropriate face. You can make only one selection.

¹ The main findings were the same across both time delays, so this factor was dropped from the main analyses.

After reading the instructions, participants were presented with an array of the 11 images depicting their own face in varying degrees of masculinity-femininity (see Fig. 2). Images were presented in a random order using E-Prime stimulus presentation software (Psychology Software Tools, Pittsburgh, PA) and remained on the screen until the participant made a selection. At the conclusion of the last test session, participants were asked to identify which test session they believed they had received the testosterone. A binomial test indicated that participants were no better than chance at guessing which day they received testosterone ($p > .200$).

2.4. Initial processing of data

Blood samples were assayed for total testosterone concentrations using commercially-available enzyme immunoassay kits (EIA-1559—DRG International). All samples were assayed in duplicate and the averages for each sample were used for statistical analyses. The intra- and inter-assay coefficients of variation were 4.19% and 5.34%, respectively. The image that the participant chose as their own during the experimental and control sessions was coded as percent masculine or feminine relative to the original face, such that more masculine versions were coded as positive values, the original face was coded as zero, and more feminine versions were coded as negative values (i.e., range was -75% to $+75\%$).

3. Results

As previously reported using this sample of men, there was a significant increase in serum testosterone concentrations after AndroGel®, but not placebo administration (Carré et al., 2015). Testosterone concentrations were significantly higher after AndroGel® versus placebo at 1 h ($M_{\text{Testosterone}} = 6.9$ ng/mL versus $M_{\text{Placebo}} = 4.7$ ng/mL; $t_{27} = 5.59$, $p < .001$, Cohen's $d = 1.13$) and 2 h ($M_{\text{Testosterone}} = 6.4$ ng/mL versus $M_{\text{Placebo}} = 4.6$ ng/mL, $t_{29} = 7.39$, $p < .001$, Cohen's $d = 1.37$) after drug administration. There were no differences in serum testosterone concentrations prior to drug application ($M_{\text{Testosterone}} = 4.2$ ng/mL versus $M_{\text{Placebo}} = 4.3$ ng/mL; $t_{29} = .53$, $p = .60$, Cohen's $d = .13$).

Our primary analysis employed a Wilcoxon signed-rank test, which is a non-parametric paired difference test that is appropriate for relatively small samples and which does not require data to be normally distributed. A Wilcoxon signed-rank test

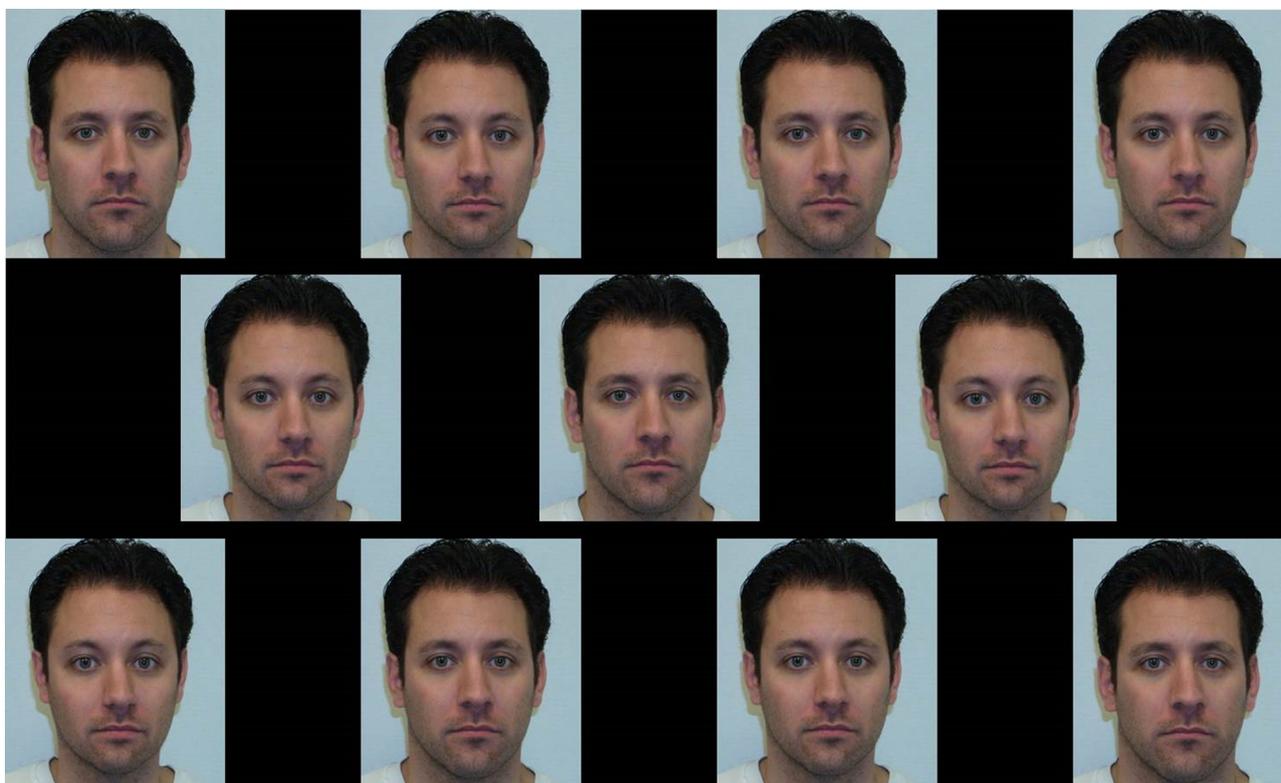


Fig. 2. The photo array from which participants selected which face they believed to be their original, unaltered face. The 11 images that varied in sexually dimorphic 2D shape were presented in a random order and remained on the screen until a selection was made.

revealed a significant increase in self-perceived facial masculinity after testosterone administration, $Z = -1.97$, $p = .049$, with a small-moderate effect size ($r = .25$). Specifically, men picked a more masculine version of their own face after testosterone administration ($M_{\text{Testosterone}} = 5.5$, $SE = 5.82$) than after placebo administration ($M_{\text{Placebo}} = -6.0$, $SE = 6.59$). Separate Wilcoxon Signed-Rank tests were performed for men with high versus low baseline testosterone concentrations (determined via median split) in order to examine the extent to which baseline testosterone concentrations moderate the relationship between drug administration and changes in dominance perception. For men with relatively low baseline testosterone concentrations, there was a significant effect of exogenous testosterone on self-perception of facial masculinity, $Z = 2.25$, $p = .020$, $r = .41$. Here, testosterone caused an increase in self-perception of facial masculinity ($M_{\text{Testosterone}} = 4.00$, $SE = 6.46$) compared to placebo ($M_{\text{Placebo}} = -17.00$, $SE = 9.24$). For men with relatively high baseline testosterone concentrations, there was no effect of exogenous testosterone on self-perception of facial masculinity, $Z = .04$, $p > .250$, $r = .01$. Men with high baseline testosterone rated themselves as relatively more masculine, irrespective of drug condition ($M_{\text{Testosterone}} = 7.00$, $SE = 10.34$, $M_{\text{Placebo}} = 5.00$, $SE = 8.49$; see Fig. 3). We also examined the extent to which baseline testosterone concentrations would moderate the effect of drug condition on self-perceived facial masculinity with testosterone entered as a continuous variable. For this analysis, we used a repeated-measures ANOVA on self-perceived masculinity scores with drug condition (testosterone versus placebo) as a within-subject factor and baseline testosterone concentrations (mean-centered) as a covariate. This analysis yielded a significant main effect of drug condition ($F_{1,28} = 4.24$, $p = .049$, $\eta_p^2 = .13$) and a significant drug condition X baseline testosterone interaction ($F_{1,28} = 5.02$, $p = .033$, $\eta_p^2 = .15$). Simple slopes analyses were performed for individuals scoring relatively low or high (± 1 SD from the mean) in baseline testosterone concentrations. Results revealed a significant difference

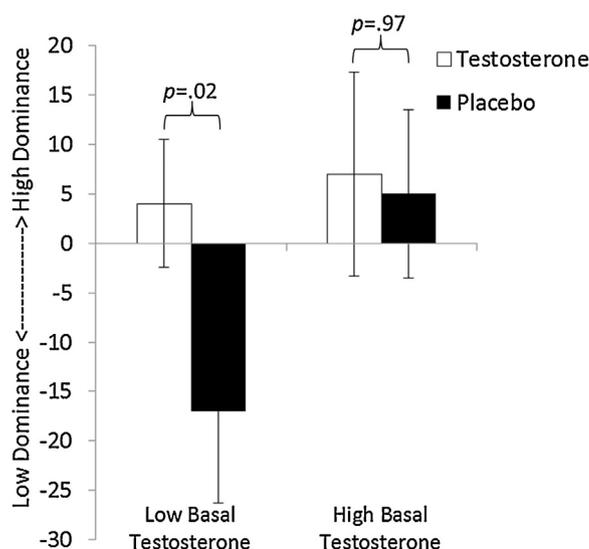


Fig. 3. The influence of exogenous testosterone administration versus placebo on the masculinity of the face chosen among men with low baseline testosterone and men with high baseline testosterone. Men with low baseline testosterone chose a significantly more dominant version of their own face when administered testosterone than when administered placebo, whereas men with relatively high baseline testosterone showed no significant change as a function of drug condition.

between the testosterone and placebo treatments among men with low baseline (i.e., pre-treatment) testosterone level ($t_{29} = 3.04$, $p = .005$), whereby men chose a much more dominant version of their face when administered testosterone ($M = 15.28$, $SE = 8.31$) versus placebo ($M = -8.96$, $SE = 9.40$). There was no equivalent finding among men who were comparatively higher in baseline testosterone ($t_{29} = .15$, $p = .88$).

Next, we repeated analyses with the inclusion of several covariates. The covariates were included because of previously established relationships with testosterone (e.g., mating strategy, aggression), or to rule out other aspects of physical formidability (i.e., height and weight). Repeating the above analyses, including age, height, or weight as covariates, or relationship status as a between-subjects factor, did not significantly change these results. Also, including baseline scores from the SOI-R (Penke and Asendorpf, 2008) or the Buss–Perry Aggression Questionnaire (Buss and Perry, 1992) as covariates had no impact on the overall findings.

3.1. Supplementary analyses

We performed additional exploratory analyses in light of previous work from this sample of men demonstrating that 2D:4D ratio and psychopathic traits moderated the effect of testosterone administration on socio-cognitive performance (Carré et al., 2015). Separate repeated-measures ANCOVAs on self-perceived masculinity scores were performed with drug condition as a within-subject factor (testosterone versus placebo) and the following covariates (mean-centered): left hand 2D:4D ratio, right hand 2D:4D ratio, Factor 1 of psychopathy (i.e., interpersonal/affective items), and Factor 2 of psychopathy (i.e., lifestyle/antisocial items). Results indicated that none of the covariates interacted with drug condition to predict variability in self-perceived facial masculinity scores (p values ranged between .23 and .93).²

4. Discussion

The current research provides the first experimental evidence that testosterone increases healthy men's self-perceived dominance as assessed using an implicit measure of dominance (i.e., self-perceived facial masculinity; see Boothroyd et al., 2007; Perrett et al., 1998). These findings are consistent with correlational work indicating that individual differences in baseline testosterone concentrations are positively correlated with self-report measures of dominance (Carré et al., 2009; Sellers et al., 2007; Turan et al., 2014). Importantly, our results indicate that the effect of exogenous testosterone on self-perceived dominance was qualified by individual differences in baseline testosterone concentrations; men with relatively low baseline testosterone concentrations pick faces that are relatively feminized (i.e., less dominant; Boothroyd et al., 2007; Perrett et al., 1998) when on placebo, but pick faces that are relatively masculinized (i.e., more dominant) when administered testosterone. In contrast, perceptions did not change as a function of testosterone among men with higher concentrations of baseline testosterone. Interestingly, the testosterone-related increase in perceptions of facial masculinity among low testosterone men brings their perceptions in line with those higher in baseline testosterone. These results suggest that testosterone impacts men's perceptions of their own physical dominance, but that its influence is relative to a person's typical endogenous hormone concentrations.

Previous work suggests that competitive interactions modulate processes relevant to mating effort, including perceptions of others' facial dominance (Watkins and Jones, 2012), preferences for facial femininity (Welling et al., 2013), and aggressive behavior (Carré et al., 2013). A growing body of evidence indicates that competition-induced changes in testosterone may underlie shifts in mating effort, as indexed by outcomes such as competitive motivation (Mehta and Josephs, 2006), risk-taking (Apicella et al., 2014), mate-seeking (van der Meij et al., 2012), and aggression (reviewed

in Carré and Olmstead, 2015). Recent work in non-human species provides compelling support for the idea that competition-induced testosterone responses play a causal role in modulating mating effort (reviewed in Gleason et al., 2009). In particular, a rise in testosterone during competition may cause an increase in one's probability of winning future encounters (e.g., Fuxjager and Marler, 2010; Mehta and Josephs, 2006) and an increase in aggressive behavior (Carré et al., 2013). Although the current study contained no competitive task, the exogenous administration of testosterone mimics a post-win increase in testosterone and likely acts on male psychology in a similar way. If ancestral men competed with other men for resources (see Puts, 2010), then cues to competitive ability (e.g., facial dominance) would have been highly relevant. Of course, we are not suggesting that administration of testosterone changes aspects of face shape, but it is noteworthy that an increase in testosterone can change the beliefs men have about whether or not they possess these physical cues to dominance. If men believe they are more dominant, and thus more likely to be successful in contest competitions, they may be more likely to engage in and win those contests. Correspondingly, increases in men's testosterone may decrease their perceptions of the physical dominance of other men (i.e., to underestimate a conspecific's physical formidability), thereby increasing the self-perceived chances of a successful outcome should an aggressive encounter occur. Indeed, one study found that men with intermediate levels of endogenous testosterone rated other men the lowest on perceived dominance compared to men with relatively low or high testosterone (Wolff and Puts, 2010), but experimental work using exogenous hormones is lacking.

Our use of a double-blind, placebo-controlled, within-subjects design rules out experimenter bias and the placebo effect. Importantly, our design also accounts for the substantial variation in circulating hormone concentrations between participants (e.g., Zitzmann and Nieschlag, 2001). Despite this, we find strong evidence that individual differences in basal testosterone concentrations influence the degree to which testosterone modulates men's perceptions of their own physical dominance. This finding may explain disagreement in the literature regarding the relationship between testosterone and dominance. Specifically, although some previous research failed to find a link between self-reported dominance and testosterone concentrations (e.g., Josephs et al., 2006), these inconsistencies may be explained by differences in basal testosterone concentrations between samples. In light of the current findings, consideration of basal testosterone concentrations will be crucial in future research in which testosterone concentrations are experimentally manipulated.

The current work is not without limitations. For instance, the current study used a relatively small sample size, although it is relatively large compared to other testosterone administration studies conducted in women (reviewed in Bos et al., 2012). Additionally, our measure of dominance may not be explicit enough and may only be measuring either the related construct of masculinity or another confounding variable (e.g., perceived trustworthiness). On the other hand, dominance and masculinity are highly correlated in men (e.g., Boothroyd et al., 2007) and facial masculinity predicts several aspects of male dominance, such as physical strength (Fink et al., 2007) and social status (Mueller and Mazur, 1996), suggesting that physical masculinity signals male dominance. In fact, Oosterhof and Todorov (2008) constructed face images along a dominance continuum using computer models based on behavioral data and used the generated face images across several face perception studies. Faces manipulated along the dominance continuum to appear more dominant were perceived as more masculine, whereas faces manipulated to appear less dominant were perceived as comparably more feminine. Similarly, Watkins et al. (2010b), using the same image manipulation techniques as the present study,

² Full results for the covariate analyses are available from the corresponding authors upon request.

found that masculinized male faces are consistently perceived as more physically and socially dominant than relatively feminine male faces. Likewise, several published studies have manipulated facial masculinity as a means of measuring perceptions of dominance (e.g., Jones et al., 2010; Main et al., 2009; Watkins and Jones, 2012; Watkins et al., 2010a,b). Thus, although it remains possible that our manipulation influenced perceptions of a related construct, previous research indicates that our manipulation is appropriate for investigating self-perceived dominance because manipulating facial masculinity reliably influences perceptions of dominance in the predicted way. Also, a more implicit measure of dominance like that used in the current study avoids, or at least minimizes, the potential introduction of demand characteristics that could lead to participant reactivity. Furthermore, it is possible that testosterone only impacts implicit measures of dominance and not more explicit measures. Testosterone is correlated with implicit power motivation, a measure of subconscious dominance motivation (Stanton and Schultheiss, 2009), but is not necessarily correlated with more explicit measures of dominance such as self-reported dominance (Josephs et al., 2006; van der Meij et al., 2008 but see Carré et al., 2009; Sellers et al., 2007; Turan et al., 2014). Thus, testosterone may serve as an indicator of a subconscious drive for dominance with separate links to behavior than self-rated dominance (Stanton and Schultheiss, 2009). Alternatively, it is possible that our masculinity manipulation is influencing men's perceptions of their own attractiveness, given that male masculinity is considered sexually attractive (e.g., Little et al., 2002), or that the testosterone-dependent changes in facial self-perception observed here could reflect a non-functional by-product of other changes in self-perception. These possibilities should be explored more fully in future research.

Another limitation of the current study is that we did not include women in our sample. Endogenous testosterone has been linked to several aspects of women's behavior and preferences, such as the reward value of cuteness in infant faces (Hahn et al., 2015). Moreover, endogenous testosterone has been similarly linked to aggression (Carré et al., 2013; Denson et al., 2013) and preferences for sexually dimorphic traits in potential mates (Welling et al., 2007, 2008) in both men and women. Indeed, the effects of testosterone on neural and behavioral processes appear to be similar across the sexes; a single administration of testosterone increases threat-related amygdala function in both men (Goetz et al., 2014) and women (e.g., Hermans et al., 2008). Investigating changes in preferences and other changes in perception among women using a within-subjects experimental design will be important to determine sex differences and/or similarities in the effects of testosterone on social perception and behavior.

The current study opens up other avenues for future research. Researchers could examine the influence of exogenous testosterone administration on other traits known to be related to endogenous testosterone (e.g., sensation-seeking; Aluja and Torrubia, 2004) and on perception of masculinity or dominance in other domains (e.g., vocal masculinity, behavioral dominance). We speculate that an increase in self-perceived dominance may represent a psychological mechanism through which testosterone mediates the tradeoff in mating versus parenting effort. Given known associations between male testosterone and reduced parenting effort (Gettler et al., 2011), that more masculine men are perceived to be both more dominant and worse parents than less masculine men (Perrett et al., 1998), and that dominance (e.g., Puts et al., 2006) and related constructs (i.e., athletic ability and masculinity; Faurie et al., 2004) are associated with a higher number of sexual partners, increased perception of one's dominance may subsequently increase mating effort and decrease parenting effort. Specifically, perception of one's own dominance may mediate the effect of testosterone on mating effort (e.g., aggression, risk-taking,

mate-seeking) at the cost of parenting effort. Future research will be required to explicitly test these relationships.

5. Conclusions

The current study is the first to investigate the influence of exogenous testosterone on men's perceptions of their own masculinity using a within-subject, placebo-controlled experimental design. Our findings provide compelling evidence that testosterone influences men's self-perceived physical dominance among men with relatively low baseline testosterone concentrations. Researchers should continue to tease apart the causal influence of testosterone on behavior and person perception using exogenous hormones and experimental methods. This work can serve as a model for future experimental behavioral endocrinology research and, crucially, highlights the necessity for researchers to consider endogenous basal testosterone concentrations in future investigations.

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Author contributions

L. L. M. Welling and J. M. Carré developed the study concept. L. L. M. Welling, J. M. Carré, and S. Hansen contributed to the study design. Testing and data collection were performed by B. J. P. Moreau and B. M. Bird. L. L. M. Welling performed the data analysis and interpretation, and drafted the manuscript. B. J. P. Moreau, B. M. Bird, S. Hansen, and J. M. Carré provided critical revisions. All authors approved the final version of the manuscript for submission.

Conflicts of interest

None.

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