

The role of exogenous testosterone and social environment on the expression of sociosexuality and status-seeking behaviors in young Chilean men

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ABSTRACT

Testosterone plays an important role as a social hormone. Current evidence suggests that testosterone is positively related to sociosexuality increasing the psychological attitudes toward investing in short-term versus long-term mating and promotes status-seeking behaviors both by dominance and prestige. In addition, the social environment may play an important role in the expression of mating effort through changes in sociosexuality and status-seeking behaviors. However, the causal relationships among the mentioned variables are still debated. We employed a double-blind, placebo-controlled within-individual design, in order to test and integrate the proposed causal relationships between testosterone and social environment over short-term and long-term mating orientation and dominant and prestigious status-seeking behaviors in a sample of 95 young Chilean men. We did not find evidence that the administration of exogenous testosterone increased short-term or decreased long-term mating orientation as expected. Moreover, exogenous testosterone did not affect either aggressive or cooperative behavior failing to support the social status hypothesis. We also did not find any relationship between short or long-term mating orientation with status-seeking behaviors. Finally, we found support for the effect of social environment on sociosexual attitudes but not over status-seeking behaviors. Thus, men reported higher levels of short-term mating orientation in the presence of a woman compared to a man and no differences were found for long-term mating orientation. We argue that sociosexuality may be expressed flexibly, but contextual factors such as the presence of women seem more important than changes in testosterone levels.

1. Introduction

Testosterone is a steroid hormone that plays an important role as a social hormone affecting reproductive strategies and mating effort in many vertebrates, including humans (Gray et al., 2020; Grebe et al., 2019; Muller, 2017; Wingfield et al., 2020). In humans, mating effort can be canalized through several pathways including the seeking of multiple mating partners and thus pursuing a short-term mating strategy, seeking and investing in a single mating partner and thus pursuing a

long-term mating strategy, or acquiring and maintaining social status (Roney and Gettler, 2015). In this regard, there is evidence that shows that testosterone levels are higher in single men or men involved in uncommitted relationships compared to men involved in committed and long-term relationships (Burnham et al., 2003; Gray et al., 2020; Grebe et al., 2019; van Anders and Goldey, 2010). Moreover, the evidence suggests that testosterone levels predict relationship status, indicating that individuals with low levels of testosterone are more likely to be involved in committed relationships in the future than individuals with

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high levels (Dibble et al., 2017; van Anders and Watson, 2006). These results suggest that testosterone may promote specifically short-term but not long-term mating. In fact, levels of testosterone remain high when men involved in a relationship show interest in maintaining extra-pair sexual relationships (Edelstein et al., 2011; McIntyre et al., 2006). However, other authors argue that testosterone levels promote mating effort by both short-term and long-term mating and that changes in relationship status or fatherhood precede changes in testosterone (Gettler et al., 2011; Roney and Gettler, 2015). In addition, mating effort is affected by social context. More concretely, the presence and social interactions with potential mating partners increase the levels of testosterone and short-term mating effort in men (Arnocky et al., 2016; Roney et al., 2007). All this evidence suggests that testosterone may affect mating strategies changing the psychological attitudes toward investing in short- or long-term mating. However, both the causal relationship and the behavioral consequences—related to status acquisition—between levels of testosterone and changes in attitudes toward investing in short- or long-term mating are still debated.

Sociosexuality, understood as the individual predisposition to get involved in a sexual relationship without commitment, is a measure that has been used to assess the relative investment of individuals in short-term and long-term mating (Gangestad and Simpson, 2000; Jackson and Kirkpatrick, 2007; Simpson and Gangestad, 1991). Sociosexuality has been measured as a single continuum in which high values indicate a predisposition to seek uncommitted sexual partners (unrestricted sociosexuality) and low values a predisposition to invest in long-term mates (restricted sociosexuality) (SOI; Simpson and Gangestad, 1991). More recent conceptualizations consider sociosexuality as a multidimensional construct comprising sociosexual attitudes, desires, and behaviors (SOI-R; Penke and Asendorpf, 2008) or comprising sociosexual attitudes with two independent dimensions (short-term mating orientation and long-term mating orientation) and sociosexual behaviors (MSOI; Jackson and Kirkpatrick, 2007). In any case, since sociosexuality is a construct related to mating orientation, it has been argued that testosterone should regulate the expression of sociosexuality, especially the expression of its attitudinal dimension, but the empirical evidence of this relationship is mixed (e.g., Kordsmeyer et al., 2018; Puts et al., 2015; Stern et al., 2020). Puts et al. (2015) found that basal levels of testosterone were positively related to levels of sociosexual attitudes and desires in men but not in women. That is, men with higher levels of testosterone were more predisposed to look for uncommitted relationships and sexual diversity. They also found that this relationship is regulated through the actual success in acquiring mates, showing negative feedback (Puts et al., 2015). Moreover, Longman et al. (2018) also found a positive association between basal levels of testosterone and sociosexual attitudes and desires but not with sociosexual behavior. However, Stern et al. (2020) were not able to replicate these results in a longitudinal study. Moreover, in a cross-sectional study, they found that levels of testosterone were positively linked to unrestricted sociosexuality, only when levels of cortisol were low (Stern et al., 2020). Finally, other studies failed to find any relationship between basal levels of testosterone and sociosexuality in men (Charles and Alexander, 2011; Farrelly et al., 2015; Kordsmeyer et al., 2018; Rosenfield et al., 2022; van Anders et al., 2007).

Some potential factors could explain these mixed results. First, Puts et al. (2015) argue that testosterone effects on sociosexual attitudes and behaviors may have, in turn, a negative effect on levels of basal testosterone as suggested by the negative relationship between sociosexual behavior and testosterone when controlling for sociosexual psychology (attitudes and desires). Thus, experimental designs may complement correlational studies and help to better understand the causal relationship between testosterone and sociosexuality. In this regard, the exogenous administration of a single dose of testosterone has been used to study causal relationships between levels of testosterone and several behavioral and psychological processes (reviewed in Carré and Robinson, 2020), and could be considered a good approach for studying the

causal relationship between testosterone and sociosexuality. In addition, previous studies employed measures of sociosexuality that consider short-term and long-term mating orientation as a single dimension (SOI: Charles and Alexander, 2011; Farrelly et al., 2015; van Anders et al., 2007; SOI-R: Kordsmeyer et al., 2018; Longman et al., 2018; Puts et al., 2015; Stern et al., 2020), but there is no consensus whether testosterone affects these two mating orientations in the same or opposite way (Dibble et al., 2017; Roney and Gettler, 2015). Accordingly, the use of MSOI can contribute to shed light on this issue.

Mating effort may also be diverted toward seeking and maintaining social status. In this regard, testosterone also plays a role in promoting status-seeking behaviors in nonhumans and humans (Archer, 2006; Eisenegger et al., 2011; Wingfield et al., 2020). In humans, status may be acquired by two pathways: dominance and prestige. Whereas dominance is based on intimidation and the use of threat and aggression to gain resources, prestige is based on the ability to confer benefits to others (e.g., knowledge or prosocial behaviors) to gain access to other resources (Cheng et al., 2013; Henrich and Gil-White, 2001). According to the social status hypothesis, testosterone would be related to both pathways (Eisenegger et al., 2010), but only the link between testosterone and dominance is relatively well supported by the evidence (e.g., Archer, 2006; Geniole et al., 2020; Mazur and Booth, 1998). Testosterone levels have been positively linked to aggression, especially in competitive contexts or in response to mating cues (Archer, 2006; Geniole et al., 2020). Nevertheless, the evidence of the causal effect of testosterone in promoting aggression is discussed (Geniole et al., 2020) and seems to be dependent upon certain personality traits such as dominance and impulsivity (Carré et al., 2017). Testosterone is also linked to dominant and risk-taking behaviors (Slatcher et al., 2011) and recent studies employing exogenous testosterone found that this hormone influences the self-perception of dominance (Welling et al., 2016) and decreases the perception of third parties' dominance (Han et al., 2021). All this evidence suggests that testosterone may play an important role in acquiring status through dominance in a context that promotes competition for resources, including mating opportunities. On the other side, the link between testosterone and prestige is less clear, as some studies found that prestige and prosocial behaviors were inversely linked to testosterone levels and inversely or not related to aggression (Harris et al., 1996; Johnson et al., 2007). Conversely, another study indicates that achieving high status through prestige raises testosterone in the following months in men but not in women, indicating that past experiences of prestige may calibrate future investment in seeking and maintaining status through prestige (Cheng et al., 2018). Finally, there are studies employing exogenous testosterone supporting the social status hypothesis (Boksem et al., 2013; Dreher et al., 2016; Eisenegger et al., 2010; van Honk et al., 2012; Wu et al., 2020). These experimental studies are mainly based on women's behavior, the exceptions being the studies of Wu et al. (2020) and Dreher et al. (2016). In the first study, the authors found that the administration of exogenous testosterone increased the probability of performing an altruistic donation in the presence of an audience, supporting the social status hypothesis (Wu et al., 2020). In the second, participants in the testosterone condition punished unfair offers in the Ultimatum Game more than participants in the placebo condition but, at the same time, rewarded more fair offers (Dreher et al., 2016). However, Bird et al. (2019) found that exogenous testosterone reduced contributions in a public good game but only in high-risk men when forced to make a reflected choice. Accordingly, more studies in men are relevant to better understanding the role of testosterone in status-seeking by prestige.

Pubertal levels of testosterone may moderate the effect of circulating testosterone on mating effort through an organizing role on the central nervous system making the brain more sensitive to circulating levels (Sisk and Zehr, 2005). In this sense, the development of muscle mass and strength are closely associated with levels of pubertal testosterone (e.g., Xu et al., 2021). In addition, muscle strength in adulthood is correlated with muscle strength during adolescence in a longitudinal study (Fraser

et al., 2017) suggesting that musculature and strength may signal, to some degree, levels of pubertal testosterone. Finally, muscular mass and strength are associated with short-term mating strategy, aggression, and cooperation under intergroup conflict competition (Lukaszewski et al., 2014; Muñoz-Reyes et al., 2020; Polo et al., 2019).

Past studies investigated how testosterone is linked to both sociosexuality and status-seeking behaviors but did not integrate them. In this regard, given the evidence that the link between testosterone on status-seeking behaviors may be dependent on personality traits (Carré et al., 2017), sociosexual attitudes may represent a relevant variable affecting the pursuit of social status by dominance and prestige. On one hand, short-term mating orientation (unrestricted sociosexuality) is reported to be positively associated with the presence of traits relevant in intrasexual competition and in acquiring status through dominance like musculature, strength, or facial masculinity (Arnocky et al., 2018; Hughes and Gallup, 2003; Lukaszewski et al., 2014; Polo et al., 2019). Moreover, unrestricted sociosexuality is related to same-sex direct and indirect aggression (Cross, 2010; Davis et al., 2022) suggesting that unrestricted men are more prone to seek status through dominance. However, another study did not find support for the relationship between unrestricted sociosexuality and dominance (Simmons and Roney, 2011) indicating the need for more studies. On the other hand, the link between sociosexuality and prestigious behaviors is less explored, and indirect evidence showed null results. For instance, unrestricted sociosexuality is linked to coercive resource acquisition but unrelated to prosocial resource acquisition (Chen, 2017). Despite these results, since testosterone is proposed to be linked to short-term mating orientation on one hand, and to prestigious behaviors on the other, it can be expected to find short-term mating orientation linked to both dominant and prestigious behaviors. Finally, less is known about the relationship between long-term mating orientation and status-seeking behaviors, mainly because most studies employed a unidimensional measure of sociosexual attitudes.

In addition to testosterone levels, the social environment may play an important role in calibrating mating effort through changes in sociosexuality and status-seeking behaviors. First, mate availability influences sociosexual attitudes and desires in men (Arnocky et al., 2016). Men reported higher sociosexual attitudes and desires when primed with a condition of mate abundance compared to mate scarcity (Arnocky et al., 2016). Further evidence suggests that the presence of potential mates increases the contributions to a public good in single men suggesting that men compete to show their cooperativeness and gain social prestige (Tognetti et al., 2016). Moreover, social interaction with women is related to changes in testosterone levels in heterosexual men (Roney et al., 2007) and testosterone levels predict dominant behaviors when competing for the attention of a woman in men who perceive themselves as dominants (Slatcher et al., 2011). This evidence points toward that the presence or absence of women may be a relevant element to understanding the adjustment of mating effort in men. Finally, another potentially important factor related to the social environment is the fact of being involved in a relationship. As we mentioned before, it is not clear whether being involved in a relationship is the consequence of past testosterone levels (Dibble et al., 2017; van Anders and Watson, 2006), or whether changes in the relationship status may precede changes in testosterone levels (Gettler et al., 2011; Roney and Gettler, 2015). In the first case, we would expect that changes in testosterone promote short-term mating effort regardless of the relationship status; however, in the second case, changes in testosterone would have different effects based on whether individuals are involved in a relationship or are single. Accordingly, relationship status can be an important moderating factor when studying the effects of testosterone on mating effort.

This study has three major goals. First, we aimed to test whether changes in testosterone levels are causally linked to changes in short-term and long-term mating orientation, and in status-seeking behaviors in young men. Second, we investigated whether differences in short-

term or long-term mating orientation have behavioral consequences related to status acquisition. Finally, we investigated whether the presence of a confederate woman (i.e., a change in the social environment) increases short-term mating orientation and enhanced status-seeking behaviors compared with the absence of her. To address these goals, we employed a double-blind, placebo-controlled within-individual design in four contexts: placebo and testosterone administration in the presence of a woman confederate, and placebo and testosterone administration in the presence of a man confederate. In addition, we employed the multidimensional sociosexual inventory (MSOI; Jackson and Kirkpatrick, 2007) to account for short-term and long-term mating orientation as separate dimensions. In this regard, we set up four sets of predictions. First, considering that levels of testosterone enhance mating effort via short-term mating (Dibble et al., 2017; van Anders and Watson, 2006), we expect that individuals treated with a single dose of testosterone would report a higher short-term mating orientation and lower long-term mating orientation compared to when they are treated with a placebo gel regardless of their relationship status. This effect would be exacerbated in those individuals with high muscle mass, and strength. Second, according to the social status hypothesis (Eisenegger et al., 2010), we expect that individuals treated with a single dose of testosterone would behave more aggressively in a context in which social status can be achieved through dominance but they would behave more cooperatively when social status can be achieved through prestige. This effect would be exacerbated in those individuals with high muscle mass, and strength. Third, as a consequence of the two previous predictions, we expect to find a positive association between short-term mating orientation and both aggressive and cooperative behaviors in contexts in which status is at stake. And fourth, if the presence of evolutionary relevant variables affects the expression of mating strategies and status-seeking behaviors (Arnocky et al., 2016; Tognetti et al., 2016; Roney et al., 2007), we expect that the presence of a woman confederate would increase the short-term mating orientation, aggressive, and cooperative behaviors compared to the presence of a man confederate. Given the previous results, we expect that the relationship with prestigious behaviors may be present only in single individuals. We did not expect an effect over long-term mating orientation since the confederate woman was unknown to the participants and we expected that her presence affected only the motivation to seek uncommitted relationships.

2. Methods

2.1. Participants

Our initial sample consisted of 104 heterosexual ($N = 101$) and bisexual ($N = 3$) men aged 18 to 36 ($M = 23.13$, $SD = 3.26$) who participated in any of the phases of the study. In the first stage, 99 individuals participated but 95 attended both sessions (placebo and testosterone). From these 95 individuals, 38 participated in the second stage of the study, and 34 attended both sessions. Five individuals participated just in the second stage of the study. We recruited participants through announcements on the laboratory and institutional webpages and announcements in social media and public places. Our participants were mostly, but not exclusively, college students from the Region of Valparaíso (Chile). We targeted men from 18 to 39 years because during this age intrasexual competition and the struggle for status are more intense (see Daly and Wilson, 1989). Participants were recruited in groups of 5. These groups had to attend together in the different phases and sessions of the study. When recruiting the participants, we aimed to conform groups of people who knew each other, which facilitated the coordination and assistance of the group. To achieve this, individuals interested in participating were asked to form groups with people they knew. At the beginning of the first session, individuals were asked if they all knew each other and if this was not the case, it was noted. Four groups (two during the first phase and two

during the second phase) had 1 individual who was not known to all of them. One group during the second phase had 2 individuals who were not known to all of them. Some participants failed to show up in the second session and as a consequence, the group size was reduced by one in four groups during the first phase and in one group during the second phase. Participants received 5000 Chilean pesos (approx 7 USD) for showing up, and a variable amount of up to 15,000 Chilean pesos (approx 21 USD) based on their performance in the economic games. The data was collected in 2019. This experiment was approved by the institutional ethics committee from Universidad de Santiago de Chile (N° 030.2019) and complied with Declaration of Helsinki. All the participants were informed about the procedure and provided written informed consent before their participation.

2.2. Study design

We employed a double-blind, placebo-controlled within-individual design. Therefore, both participants and research members who interacted with them were unaware of which treatment condition participants were exposed to. The study was organized in two phases and in each phase participants received a single dose of 150 mg of testosterone gel (AndroGel®) and a single dose of 150 mg of placebo gel (alcoholic gel) in two different sessions (Fig. 1). The alcoholic gel possessed a smell and texture similar to testosterone gel. Both gels were transferred from their original containers to neutral white sachets. The administration of testosterone and placebo was counterbalanced between groups, but individuals in the same group received the same treatment either placebo or testosterone. Sessions within each phase were spaced one week (washout period), however as some groups were not able to attend in the subsequent week, sessions were spaced 2 weeks for two groups (9 individuals) and 4 weeks for one group (4 individuals) during the first phase. Two groups (10 individuals) had 4 weeks between sessions in the second phase. We decided this washout period (1 week) because we wanted to keep all the variables relatively constant (age, relationship status, muscle mass, strength, and BMI) when comparing testosterone and placebo conditions within phases. As the washout period was not the same for all the participants, we created a binary variable to control this inconsistency. Due to the low number of individuals that had a 2-week and 4-week period, we collapsed them into one category (more than a 1-week period). Accordingly, this variable was divided into individuals with a 1-week period (82 in the first phase and 28 in the

second phase) and individuals with more than a 1-week period (13 in the first phase and 10 in the second phase). The two phases of the study were spaced 5 or 6 months depending on the group's availability. The first phase was characterized by the presence of a woman confederate and the second phase by the presence of a man confederate. The inclusion of a woman confederate was to create a context of enhanced intrasexual competition among participants. Meanwhile, the man confederate was included as control to the presence of a woman in the group and to keep group size constant among stages. The groups that participated in the second phase were recaptured from those that participated in the first phase. Accordingly, participants in the second phase were the same as in the first phase, except for five individuals who were recruited during the second phase in order to keep group size constant. However, these five individuals were not considered in any of the analyses performed.

At the beginning of each experimental session, testosterone or placebo was provided to participants who were instructed on how to apply the gel. They self-administered the gel by spreading it slowly on the outer part of the arm. The gel was self-administered in isolated boxes allowing the gel to be absorbed gradually. These gels were administered between 9:00 and 9:30 and after this the individuals needed to wait 3 h for the gel to produce its effect (Carré and Olmstead, 2015). During this time and in the first session of each phase, anthropometric measures were taken. Accordingly, we assumed that muscle mass, strength, and BMI did not change within sessions (in each phase) due to the short period elapsing between them (one to four weeks). Participants were free to use their remaining waiting time. They were only instructed not to eat or drink anything other than water and to refrain from doing any exercise. After 3 h of the testosterone (or placebo) administration, participants returned to the laboratory and at this moment the confederate was introduced to them. The participants were told that she/he was participating in a similar project and at that point, she/he joined the group to perform the same procedure except for the saliva samples. Then, a first saliva sample was collected. After that, and while we finished setting up the boxes for the questionnaires, they had some time to interact or at least to be aware of the presence of this new individual in the group. This time was approximately 1 min, and confederates were instructed to be socially passive, that is, they only verbally interacted with participants if they addressed to her/him. Next, participants and the confederate completed a quick sociodemographic questionnaire, answered the multidimensional sociosexual orientation inventory, and played a public good game (7 min) and point subtraction aggression

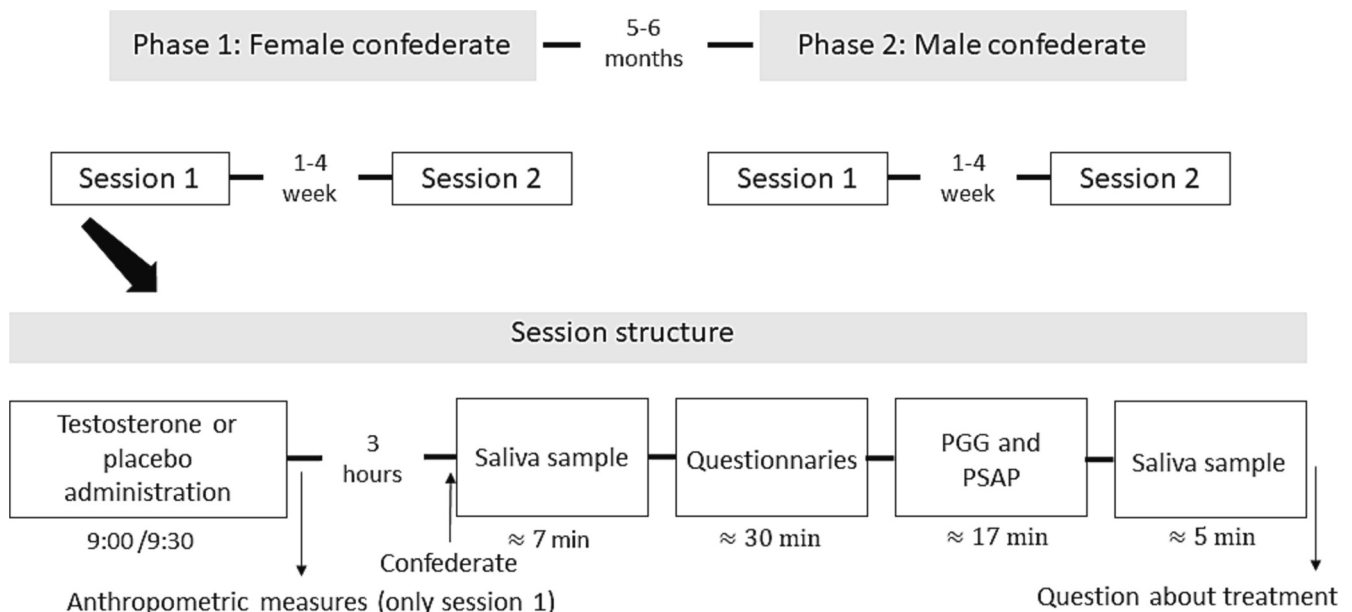


Fig. 1. Schematic representation of the study design.

paradigm (10 min). Then, a second saliva sample was collected just after the games. Finally, participants were asked if they believed they had received testosterone or placebo, or if they could not indicate either option since participants' beliefs about the treatment may influence their behavior (Eisenegger et al., 2010). Responses were grouped into two categories, those that indicated a belief that they had received testosterone and those that indicated a belief that they had received placebo or no specific belief. All the questionnaires and games were played on isolated boxes.

2.3. Psychometric measurements

2.3.1. Sociodemographic questionnaire

Participants answered a general sociodemographic questionnaire with questions about their age, relationship status (single or paired), months in the relationship (if they are paired), socioeconomic status, origin, sexual orientation, educational level, and sex.

2.3.2. Multidimensional Sociosexual Orientation Inventory (MSOI)

Participants completed a Chilean adaptation of the multidimensional sociosexual orientation inventory (Jackson and Kirkpatrick, 2007). This questionnaire is composed of 22 items and is based on a three-factor model comprising: a short-term mating orientation scale composed of 10 items, a long-term mating orientation scale composed of 7 items, and a measure of previous sexual behavior composed of 3 items. Short-term and long-term mating orientation are independent dimensions of sociosexual attitudes and allow us to have a more pluralistic view of mating psychology by recognizing that the same person can be both long- and short-term oriented simultaneously (Jackson and Kirkpatrick, 2007). These attitudinal items are responded using a 7-point Likert scale (1 = strongly disagree to 7 = strongly agree). The other factor represents the sociosexual behavior component and the items are responded with a numeric answer. For the purpose of this study, we employed only the attitudinal dimension. For short-term mating orientation, we obtained a Cronbach- α of 0.911 in the placebo condition and 0.895 for the testosterone condition. For long-term mating orientation, we obtained a Cronbach- α of 0.887 in the placebo condition and 0.863 for the testosterone condition.

2.4. Morphometric measurements

2.4.1. Strength

Hand grip strength is a widely used measure of upper-body strength, which in turn correlates with fighting ability (Muñoz-Reyes et al., 2012; Sell et al., 2012). It was estimated from a hydraulic hand grip dynamometer (Jamar® 5030 J1) following Muñoz-Reyes et al. (2012) protocol. Measurements were recorded in three alternating trials for each hand. The maximum hand grip strength (of both hands) was used in the analyses.

2.4.2. Muscle composition

Skeletal muscle mass (kg), was assessed with a body composition analyzer (Inbody 370). This device employs a tetrapolar 8-point tactile electrode for measurements through a direct segmental multifrequency bioelectrical impedance analysis method (DSM-BIA). The DSM-BIA is a valid tool for the assessment of total and segmental body composition (Ling et al., 2011).

2.4.3. Body mass index (BMI)

This is a measure that covariates with strength and muscle mass and, accordingly, it is convenient to control its effect on them when studying strength and muscle mass relationships with other traits. The participant's weight was measured using a body composition analyzer (Inbody 370) and their height was obtained using a stadiometer, in order to calculate BMI.

2.5. Behavioral measurements

2.5.1. Aggressive measurement. The Point Subtraction Aggression Paradigm (PSAP)

This computer task was first performed in the 80s by Cherek (1981) and it is a highly reliable tool to estimate aggression, especially in men (Geniole et al., 2017). The objective of the task is to win as many points as they can, which will later be exchanged for real money. Participants played against a fictional opponent, although they were told that they were playing with real individuals performing this same task in another university, and have three button-operated options, that cannot be performed at the same time: a) Gaining points: Participants can gain 1 point by pressing consecutively 100 times the button A. b) Aggression: Participants can subtract 1 point from the other participant by pressing 10 times the button B. Points are not added to their personal account. c) Protection: Participants can prevent losing points by pressing button C 10 times. We applied a similar protocol performed by Carré and McCormick (2008) but with one round of 10 min. Regardless of the composition of the experimental group (same-sex or mixed-sex), participants were told that they were going to play with a same-sex opponent without knowing his identity. It is relevant to note that to give more ecological validity and to take into account the relevance of aggression for intragroup status, we followed the strategy used by Geniole et al. (2017). In this version, men are intensively attacked (i.e., points were subtracted to them frequently), as an indirect measure of status loss. We employed as a measure of aggression the number of times key B was pressed in relation to the total number of keys pressed in order to control for differences in speed. This measure was expressed as a percentage.

2.5.2. Cooperative measurement. Public Goods Game (PGG)

In this game, individuals have an initial amount of money. They can choose to invest all, some part, or nothing of this money in a common pool. Once all the participants have made their choices, the common pool will be multiplied by 2 and the total amount will be equally distributed among all participants regardless of their contribution. Therefore, this game is a social dilemma in which individuals face a trade-off between pursuing a cooperative or a selfish outcome (Ostrom, 2001). Participants played three rounds of this game and at the end of each round researchers announced the person or persons who had contributed the most by their number and name in order to be identified by the other individuals. Thus, we aimed to create a context in which participants may compete to be the most cooperative in the group and according to the competitive altruism hypothesis (Hardy and Van Vugt, 2006) to gain prestige among group members. All participants started each round with 1.500 Chilean pesos. The Public Goods Game was played on computers and, although individuals were not able to observe or know others' contributions, the identities were known (i.e., non-anonymous game). Confederate woman and man participated in the public goods games with a fixed quantity of 750 Chilean pesos and were never announced as the top contributors. We employed the difference in the contribution between the third and first rounds as a measure of the individual effort to gain status through prestige. In addition, we employed the contribution in the third round as an additional measure of this effort.

2.6. The measure of circulating testosterone

This was measured following the protocol used by Sanchez-Page and Turiegano (2010), and complemented by Mehta et al. (2015). Two samples of circulating testosterone were obtained from saliva provided by subjects in the study. Participants were asked not to drink or eat anything apart from water 1 h before the study started. At the beginning of the experimental session, participants were asked to spit through a straw into a saliva sampling device (Sali-tubes 100, DRG). At the end of the experimental process, participants were asked to provide a second saliva sample. A lack of delay between the experimental procedure and

the second testosterone measure allowed us to capture the effect of the social interaction on circulating testosterone levels, separated from the effect of winning or losing the interaction, as prior studies have demonstrated that the hormonal and psychological effects derived from winning or losing a competition are delayed 15–20 min (Casto and Edwards, 2016). Saliva samples were immediately centrifuged, frozen, and stored at -20°C . All samples were analyzed employing Testosterone Enzyme Immunoassay Kits (Salivary testosterone ELISA kit from Salimetrics©) following the manufacturer's instructions. Results from ELISA assays showed abnormally high values of testosterone concentrations. Most of the results were outside the calibration curve (sigmoidal 4-parameter logistic curve) and around 64 % of the sample could not be interpolated. The analyses were repeated several times using dilutions (1:5 dilutions), but the results did not improve. For this reason, we were not able to report and use the circulating testosterone data in this study. Although the causes for these abnormal values were not identified with certainty, we initially suspect that the kits used were damaged due to the loss of the cold chain since the standard curves showed abnormal values, especially the values corresponding to high testosterone concentrations. However, another plausible explanation is that our samples were contaminated with testosterone gel.

2.7. Data analysis

First, we employed Pearson correlation coefficients to analyze correlations between our continuous independent variables. Since strength and muscle mass were highly correlated, we decided to select muscle mass for the analysis in order to avoid collinearity. Then, we fitted different hierarchical linear models to address each proposed prediction, considering within-subject measures as level-1 variables, and between-subject measures as level-2 variables. We used data from the first stage of the study (when participants played with a woman confederate) and from individuals that attended both sessions, that is, participants whom we were able to calculate washout periods ($N = 95$), to test predictions one, two, and three. These three predictions do not consider the group composition as a factor. For the first prediction, we fitted two hierarchical linear models considering as dependent variables the short-term mating orientation in the first model and long-term mating orientation in the second one. The following variables were considered in both models: the hormonal treatment- placebo or testosterone -, as the independent variable, and muscle mass as a covariable. We analyzed the interaction between hormonal treatment and muscle mass. To test the second and third predictions, we fitted three hierarchical linear models considering as dependent variables the variation in the amount of money donated in the Public Goods Game between the third and first rounds in the first model, the amount of money donated in the third round of the Public Goods Game in the second model and the aggressive behavior displayed in the Point Subtraction Aggression Paradigm in the third model. The independent variable, covariate, and interaction were the same as in the models regarding our first prediction except that we added as covariables the short-term mating orientation and long-term mating orientation to test prediction 3. Finally, to test our fourth prediction, we added data from the second phase of our study excluding one bisexual man since this prediction is based on opposite-sex mating, 4 individuals who did not participate in both sessions, and the 5 individuals who only participated in the second phase ($N = 33$). As we measured all the morphometric measures again, all our variables were level-1 (within individual variables). We fitted five hierarchical linear models considering as dependent variables the short-term mating orientation in the first model, long-term mating orientation in the second model, the variation in the amount of money donated in the Public Goods Game between the third and first rounds in the third model and the amount of money donated in the third round of the Public Goods Game in the fourth model and the aggressive behavior displayed in the Point Subtraction Aggression Paradigm in the fifth model. For all these models, the hormonal treatment and the presence or absence of a

woman confederate were our independent variables and muscle mass was our covariable. We analyzed the interactions between the hormonal treatment with muscle mass and the interaction between the presence or absence of a woman confederate and relationship status for models regarding cooperative behavior. In all models, we considered age, body mass index, relationship status (single or paired), order of treatment, the response to the question about the treatment, and washout period between sessions (1 week or >1 week) as control variables. Despite that we expected that testosterone would affect mating effort (short-term mating orientation and status-seeking behaviors) regardless of relationship status, we included the interaction between relationship status and treatment to explore the possibility that the testosterone administration had affected differentially single and paired individuals.

Before performing the analyses, we standardized all the variables. Whenever two-way interactions between factors were significant, we performed a pair-wise comparison with Sidak corrections. Whenever two-way interactions between factor and continuous variable were significant, we fitted a reduced model including only the significant factors in order to interpret the interaction. Since hierarchical linear models entail residuals at different levels, we calculated for each significant parameter the effect size following the following expression:

$$f^2 = \frac{R_2^2 - R_1^2}{1 - R_2^2}$$

where R_2^2 represents the variance explained for a full model and R_1^2 the variance explained for a model in which a given effect was removed (Lorah, 2018). In order to calculate R^2 of the models, we employed the following expression:

$$R^2 = 1 - \frac{\sigma_F^2 + \tau_F^2}{\sigma_E^2 + \tau_E^2}$$

where σ_F^2 is level-1 error variance of the full model, τ_F^2 is level-2 error variance of the full model, σ_E^2 is level-1 error variance of the empty or null model and τ_E^2 is level-2 error variance of the empty or null model (Lorah, 2018).

We decided to employ generalized hierarchical linear models to deal with the repeated measures of the data. We specified a normal distribution and an identity link function. Individual ID was included as the random effect in all of our models and an unstructured covariance for the random-effect model was specified. We employed the Satterthwaite approximation to calculate degrees of freedom since our sample is small and robust methods to estimate parameters in order to control for potential outliers and deviations from the model assumptions. All the analyses were performed with IBM SPSS statistic 25 software. We set up a significant level of $\alpha = 0.05$ and two-tails analysis.

The hypothesis and analyses were preregistered in OSF after the data was collected (<https://osf.io/ys8x6>). Data can be accessed through the following link: https://osf.io/ef62y/?view_only=3d6472bd2f1144af8e15f18b19ff40c8. The delay between the last data collected and pre-registration was due to the suspension of the laboratory's activity due to the covid pandemic. This suspension affected the ongoing data collection and hormonal analysis. The analysis of the last saliva samples was performed in October 2021 in Spain. After that, we considered continuing with the data collection, but we finally abandoned that possibility and performed the pre-registration of the hypotheses and analyses in July 2022. We then proceeded to prepare the data for analysis, analyze the data, and write and edit the manuscript. There were some deviations from the preregistration. First, we added four more models in prediction 4 to test the effect of the presence or absence of a woman in the group in relation to the display of status-seeking behaviors. Second, for prediction 3, we did not analyze the interaction between hormonal treatment and mating orientation in order to explain status-seeking behaviors since this prediction was proved not to be justified at the theoretical level. Third, we employed a robust parameter

estimation to deal with potential outliers. Fourth, we excluded one bisexual man from prediction 4 following a reviewer's suggestion, since this prediction is based on opposite-sex mating. Fifth, we added the washout period as a control variable and we explored the potential moderator effect of the relationship status with the treatment following reviewers' suggestions. And finally, we excluded the 2D:4D measure from all the analyses because is no longer considered a valid measure of prenatal levels of testosterone (Sorokowski and Kowal, 2024).

3. Results

Table 1 shows descriptive statistics for level-1 and level-2 variables across treatments and phases (presence of a woman or a man). Table 2 shows Pearson correlation coefficients for our independent variables.

Regarding our first prediction (Table 3), we did not find any effect of treatment on the expression of short-term mating orientation either as a main effect ($F(1,7) = 0.387, p = .552$) or in interaction with muscle mass ($F(1,16) = 0.018, p = .895$) or relationship status ($F(1,53) = 0.097, p = .756$). We only found an interaction effect between treatment and BMI ($F(1,15) = 8.799, p = .010, f^2 = 0.001$). As this interaction was the only significant effect in the model, and in order to interpret it, we fitted a reduced model only containing the interaction. We found that BMI was negatively related to short-term mating orientation in the placebo condition ($Slope_{BMI} = -0.071$) but positively related in the testosterone condition ($Slope_{BMI} = 0.034$). To interpret this result considering the repeated measures, we divided BMI into three categories representing individuals in the lower third, in the intermedium third, and in the higher third of the BMI range. Results from *t*-tests for repeated measures for each category showed that the administration of testosterone increased the expression of short-term mating orientation in men in the higher third of the BMI range (mean differences = 0.169, $t = 2.140, df = 31, p = .040$) but no differences were found in the lower third (mean differences = -0.145, $t = -1.731, df = 30, p = .094$) or in the intermedium third (mean differences = 0.081, $t = 1.016, df = 31, p = .318$). Regarding long-term mating orientation, we did not find any effect of treatment either as a main effect ($F(1,33) = 0.530, p = .472$) or in interaction with muscle mass ($F(1,56) = 0.058, p = .810$) or relationship status ($F(1,54) = 2.191, p = .145$). However, we found significant main

Table 1
Mean and standard deviation of each variable used in the models and number of single and partnered individuals in each condition.

		Mean (Std. Deviation)			
		Phase 1		Phase 2	
		Control (N = 99)	Treatment (N = 95)	Control (N = 37)	Treatment (N = 42)
Mating orientation	Short-term	4.87 (1.30)	4.93 (1.25)	4.48 (1.00)	4.48 (1.00)
	Long-term	5.08 (1.26)	5.01 (1.24)	4.47 (0.83)	4.56 (0.85)
Contribution in PGG (CLP)	Round 1	1189 (463)	1224 (445)	1304 (363)	1408 (218)
	Round 3	1177 (515)	1129 (560)	1149 (567)	1304 (394)
	Difference between rounds	-13 (513)	-95 (581)	-156 (581)	-104 (374)
Proportion of steals		3.87 (6.13)	3.27 (5.99)	1.25 (1.92)	5.15 (17.71)
Relationship status (single/ paired)		59/40	59/36	26/11	31/11
Muscle mass (kg)		32.34 (4.02) (N = 99)		32.08 (4.52) (N = 42)	
Strength (kg)		47.54 (7.97) (N = 99)		46.13 (7.93) (N = 40)	
2D:4D		0.94 (0.03) (N = 96)		0.94 (0.03) (N = 37)	
BMI		24.03 (2.88) (N = 99)		23.30 (2.97) (N = 42)	
Age (years)		23.10 (3.26) (N = 99)		22.83 (2.69) (N = 42)	

Note: PGG: Public Good Game, BMI: Body mass index.

Table 2

Correlations between independent variables in the first stage of the study under placebo condition (above the diagonal) and testosterone condition (below the diagonal).

	Muscle mass	Strength	2D:4D	BMI	Age
Muscle mass		0.677***	0.096	0.438**	0.132
Strength	0.690***		-0.037	0.248*	0.158
2D:4D	0.097	-0.033		0.095	-0.008
BMI	0.431**	0.254*	0.109		0.296**
Age	0.133	0.144	-0.004	0.308**	

Note: BMI: Body mass index.

Table 3

Generalized linear mixed models' coefficients for predictions 1 and 4.

	STMO		LTMO	
	β pre. 1	β pre. 4	β pre. 1	β pre. 4
Intercept	0.236	-0.449	0.283	0.160
Treatment = 0	-0.034	-0.030	-0.043	-0.064
Relationship Status = 0	0.056	0.029	-0.511**	-0.344*
Order = 0	0.046	0.217	0.067	0.061
Final question = 0	-0.033	-0.006	-0.109	-0.155
Washout = 0	-0.302	-0.176	0.040	0.042
Confederate = 0	-	0.573**	-	0.166
BMI	-0.064	-0.031	-0.013	0.040
Muscle mass	0.024	0.027	-0.014	0.036
Age	0.200	0.158	0.211*	0.186*
Treatment = 0 * Muscle mass	-0.005	-0.003	0.013	0.027
Treatment = 0 * RS	0.023	0.006	0.170	0.176
Treatment = 0 * BMI	-0.100*	-0.102**	0.043	0.030

STMO, LTMO, BMI, Muscle mass, and 2d:4d were z-standardized prior to fitting models.

STMO: Short-term mating orientation, LTMO: Long-term mating orientation, Treatment = 0: Control condition, Relationship Status = 0: Single individuals, Order = 0: First control condition, Final question = 0: Placebo or I don't know, Confederate = 0: women confederate, Washout = 0: 1-week period.

Bold figures indicate significant coefficients.

* $p < .05$.

** $p < .01$.

effects of relationship status ($F(1,10) = 8.403, p = .016, f^2 = 0.042$) and age ($F(1,46) = 5.367, p = .025, f^2 = 0.031$). Single individuals showed lower long-term mating orientation than paired individuals (mean difference = -0.426, $t = -2.899, df = 10, p = .016$), whereas age was positively related to long-term mating orientation ($\beta_{age} = 0.211; t = 2.317; p = .025$).

Regarding our second hypothesis (Table 4), we did not find a main effect of treatment on the difference of contributions in the Public Goods Game ($F(1,48) = 0.510, p = .478$), or in interaction with muscle mass ($F(1,24) = 2.990, p = .096$) or relationship status ($F(1,32) = 0.571, p = .455$). No other significant parameters were found in this model. If we consider only contributions in the final round, we did not find an effect of treatment either as a main effect ($F(1,45) = 0.281, p = .599$) or in interaction with muscle mass ($F(1,35) = 1.016, p = .320$) or relationship status ($F(1,41) = 0.285, p = .597$). However, we found a main effect of order ($F(1,76) = 5.754, p = .019, f^2 = 0.032$) and washout period ($F(1,24) = 10.928, p = .003, f^2 = 0.036$). First, individuals who were first administered with placebo contributed less in the third round compared to individuals who were first administered with testosterone (mean differences = -0.430, $t = -2.399, df = 76, p = .019$). And second, individuals with 1-week of washout period contributed less in the third round than individuals with >1-week period (mean differences = -0.669, $t = -3.306, df = 24, p = .003$). In regard to aggression in the PSAP, we did not find any effect of treatment either as a main effect ($F(1,20) = 1.370, p = .256$) or in interaction with muscle mass ($F(1,6) = 1.766, p = .229$) or relationship status ($F(1,13) = 0.812, p = .384$). We did not find any other significant effect in our control variables.

In relation to our third hypothesis, we found that short-term mating

Table 4
Generalized linear mixed models' coefficients for predictions 2, 3 and 4.

	Differences in contribution		Contribution in last round		Aggression in PSAP	
	β pre. 2,3	β pre. 4	β pre. 2,3	β pre. 4	β pre. 2,3	β pre. 4
Intercept	0.384	-0.476	0.802**	-0.455	-0.173	-0.274
Treatment = 0	-0.019	-0.042	-0.014	-0.084	0.009	-0.002
Relationship Status = 0	-0.142	0.170	-0.121	0.618	-0.088	0.214
Order = 0	-0.166	0.119	-0.430*	-0.004	0.180	0.118
Final question = 0	0.136	0.127	0.061	0.139	-0.090	0.100
Washout = 0	-0.418	0.042	-0.669**	0.104	0.147	0.083
Confederate = 0	-	0.418	-	0.346	-	-0.023
BMI	0.115	0.065	0.084	0.071	-0.091	-0.071
Muscle mass	-0.101	-0.072	-0.110	-0.098	0.129	0.176
Age	0.003	0.014	0.053	0.022	0.252	0.163
STMO	0.077	-	0.073	-	0.014	-
LTMO	0.045	-	0.004	-	-0.148	-
Treatment = 0 * Muscle mass	0.308	0.240	0.156	0.144	-0.167	-0.178
Treatment = 0 * RS	0.223	0.141	0.137	0.073	0.210	-0.152
Treatment = 0 * BMI	-0.188	-0.108	-0.173	-0.120	0.208	0.121
Confederate = 0 * Relationship Status = 0	-	-0.328	-	-0.765*	-	-

STMO, LTMO, BMI, Muscle mass, and 2d:4d were z-standardized prior to fitting models.

STMO: Short-term mating orientation, LTMO: Long-term mating orientation, Treatment = 0: Control condition, Relationship Status = 0: Single individuals, Order = 0: First control condition, Final question = 0: Placebo or I don't know, Confederate = 0: women confederate, Washout = 0: 1-week period.

Bold figures indicate significant coefficients.

* p < .05.

** p < .01.

orientation was not related to differences in contribution in PGG ($F(1,64) = 0.740, p = .393$), to contributions in the last round of the PGG ($F(1,84) = 0.653, p = .421$), or to aggression in the PSAP ($F(1,6) = 0.016, p = .904$). Similarly, we found that long-term mating orientation was not related to differences in contribution in PGG ($F(1,43) = 0.211, p = .649$), to contributions in the last round of the PGG ($F(1,99) = 0.002, p = .965$), or to aggression in the PSAP ($F(1,4) = 1.263, p = .323$).

In our fourth prediction and regarding mating orientation (Table 3), we found a main effect of the stage on short-term mating orientation ($F(1,6) = 40.401, p = .001; f^2 = 0.075$). Men playing with a woman confederate showed higher levels of short-term mating orientation in comparison to when they played with a man confederate (mean differences = 0.573, $t = 6.356, df = 6, p = .001$). On the other hand, we did not find a main effect of the stage on long-term mating orientation ($F(1,9) = 1.306, p = .282$). Regarding status-seeking behaviors (Table 4), the presence of a woman did not affect differences in contribution between third and first rounds in the Public Goods Game neither as a main effect ($F(1,68) = 1.983, p = .164$) nor in interaction with relationship status ($F(1,90) = 0.883, p = .350$). In addition, we found that the presence of a woman did not affect the contributions in the third round as a main effect ($F(1,93) = 0.047, p = .829$), but we found significant interaction with relationship status ($F(1,106) = 5.178, p = .025; f^2 < 0.001$). Post-hoc pair-wise comparisons using Sidak correction show that single and paired individuals did not differ in their contributions in the third round in the presence of a woman (mean differences = -0.111, $t = -0.724, df = 108, p = .471$) but single individuals contributed more than paired in the presence of a man (mean differences = 0.654, $t = 2.051, p = .042$). On the other hand, single men contribute more in the presence of a man compared to in the presence of a woman (mean differences = 0.419, $t = 2.639, df = 107, p = .010$), but no differences were found in paired men (mean differences = -0.346, $t = -1.159, df = 90, p = .250$). Finally, we found that the presence of a woman did not affect aggression in the point subtraction aggression paradigm compared to the presence of a man ($F(1,9) = 0.012, p = .914$).

4. Discussion

In this study, we tested the causal role of testosterone on sociosexual attitudes and status-seeking behaviors through dominance and prestige and how social environment may influence the expression of those

variables. Our results support only one out of four of our predictions. First, we did not find an effect of testosterone administration on short-term or long-term mating orientation. We also did not find that testosterone administration affected status-seeking behaviors. We also fail to find any effect of short-term mating orientation in the expression of status-seeking behaviors. However, we found the predicted effect of the social environment since the presence of a woman increases men's short-term mating orientation, but does not affect long-term mating orientation.

Testosterone is a social hormone that plays an important role in the allocation of time and energy in mating (Grebe et al., 2019). In this sense, an increase in circulating testosterone levels should affect the predisposition to invest in short-term mating partners versus long-term mating partners (e.g., Dibble et al., 2017). Our first prediction stated that variation in circulating testosterone levels was causally linked to changes in sociosexual attitudes, increasing short-term mating orientation and decreasing long-term mating orientation. Our results did not support our prediction since the administration of exogenous testosterone changed neither short-term nor long-term mating orientation in men compared to when they were administered a placebo gel in both single and paired individuals. Previous studies have reported that levels of testosterone vary according to relationship status and fatherhood (Burnham et al., 2003; Gettler et al., 2011; Gray et al., 2020; Grebe et al., 2019). However, the link between testosterone and relationship status was moderated by sociosexuality, that is, men involved in committed relationships maintain high levels of testosterone if they are interested in new sexual partners (McIntyre et al., 2006). Therefore, one of the possible explanations for our results is that sociosexual attitudes modulate levels of testosterone and not the other way around. In other words, it may be the case that regardless of the relationship status men with a short-term mating orientation maintain high levels of testosterone, and that changes in their sociosexual attitudes in response to social environment (Arnocky et al., 2016) are followed by a change in testosterone levels. That interpretation implies reversing the causal relationship between testosterone levels and sociosexual attitudes, which leads to the question of what other proximal mechanisms might be explaining the variability in sociosexual attitudes. An alternative explanation is related to the dual-hormone hypothesis, which states that changes in testosterone are related to behavioral responses but moderated by cortisol levels (Mehta and Prasad, 2015). In this regard, Stern

et al. (2020) in a cross-sectional study found that levels of testosterone were positively related to sociosexual attitudes when levels of cortisol were low. In our study, we were not able to measure cortisol, and therefore, our results may indicate the need to consider cortisol levels in future studies in order to find a causal relationship between levels of testosterone and sociosexual attitudes. However, in a longitudinal study, Stern et al. (2020) did not find an association between within-subject testosterone changes and sociosexual attitudes, even considering cortisol levels. The longitudinal study resembles our study more than the cross-sectional one, as we also tested within-subject testosterone changes, suggesting that our null result is not necessarily a consequence of not considering cortisol.

We found that the administration of exogenous testosterone had a significant effect but in interaction with BMI, that is, individuals with high BMI showed higher short-term mating orientation when administered with testosterone compared to placebo. This result has to be interpreted with caution since BMI was only included in the model as a control variable and no specific prediction considered it. In addition, the effect size of this result is very low, suggesting a spurious effect. In the case that this result was not spurious, a possible explanation would be that the effect of the administration of exogenous testosterone on short-term mating orientation is only salient for less attractive individuals (higher BMI) since they are less oriented toward short-term mating under non-experimental conditions (Figueroa et al., 2020; Lukaszewski et al., 2014; Weeden and Sabini, 2005). It would be interesting to include measures of physical attractiveness as a potential moderator in future studies to test this suggestion.

Our second prediction aimed to test the social status hypothesis that argues that levels of testosterone play a role in promoting status-seeking behaviors both by prestige and dominance in contexts in which the status is challenged (Eisenegger et al., 2011). Our result did not support this hypothesis. First, in the case of status acquisition by dominance, we did not find any effect of the treatment on the aggression in the PSAP. In our design, individuals were highly provoked, that is, they received a high rate of aggression from the (virtual) opponent. We assume that this aggression can be interpreted as a challenge for the status and that individuals administered with testosterone should show higher rates of reactive aggression. In fact, there is evidence that testosterone is positively associated with costly aggression in the PSAP in individuals who lost the competition, as well as in dominant winners (Carré et al., 2009). In our study, changes in testosterone were artificially induced, suggesting that increased levels of testosterone may be necessary but not enough to provoke aggression in the individuals. In this regard, contextual and psychological factors, like the presence of a previous competition or impulsivity may be necessary to elicit the dominant behavior (Carré et al., 2017). In addition, as mentioned before, levels of cortisol may play a moderating role in the effect of testosterone on behavior. Concretely, there is evidence that testosterone is positively related to dominance but only when levels of cortisol are low (Sarkar et al., 2018). In the case of prestige, our results show no relationship between the administration of testosterone and contributions in the Public Good Game. There is previous evidence showing that the exogenous administration of testosterone has a positive association with cooperative choices in the Prisoner's Dilemma and Public Goods Game (Boksem et al., 2013; Eisenegger et al., 2010; van Honk et al., 2012). However, these studies have two important differences. First, they were between-subjects designs, and second and more importantly, the participants were women. Two studies support the social status hypothesis in men using exogenous testosterone but employing a modified ultimatum game and the decision to perform an altruistic donation (Dreher et al., 2016; Wu et al., 2020). In our study, most of the individuals within the groups knew each other and this circumstance could have modified the expected dynamics of status gain through prestige within the group. In this sense, groups of unknown individuals in which there is no established prestige hierarchy might be a better setting to study the effect of testosterone on status seeking through prestige. However, even if

within the groups of this study there was some kind of hierarchy of prestige, it would also be expected that individuals would try to maintain their status and compete to exhibit themselves as the most generous, something that is characteristic of reputation-based hierarchies (Roberts, 1998). In fact, Cheng et al. (2018) found that gains of status by prestige are associated with an increase in testosterone levels that may predispose to maintain that prestigious status in future interactions. However, Bird et al. (2019) found that exogenous testosterone reduced contributions in high-risk men in the condition that they were forced to take a reflected choice in a public good game. These results could suggest a lack of a direct relationship between levels of testosterone and status-seeking behavior via prestige and the need to consider other personality and attitudinal variables (like risk-taking) in order to understand the relationship between testosterone and prestigious behaviors.

In our third prediction, we aimed to test whether short-term mating orientation was associated with status-seeking behaviors. According to the strategic pluralism hypothesis, men oriented toward short-term mating should display features related to good genes and competitive abilities (Gangestad and Simpson, 2000). Therefore, it is plausible to argue that short-term mating individuals may seek status at least throughout dominance. Despite individuals oriented toward short-term mating have been reported to show traits related to formidability like higher strength or muscular mass (Fajardo et al., 2022; Lukaszewski et al., 2014; Polo et al., 2019), our result did not show a relationship between short-term mating orientation and aggressive behavior in the PSAP. In addition, short-term mating orientation was not associated with the contributions in the Public Goods Game. Similarly, our exploratory analysis of the relationship between long-term mating orientation and status-seeking behaviors also showed null results. Acquiring and maintaining a high social status is an important factor that impacts reproductive success (e.g., Hopcroft, 2006) and it is probably important for individuals oriented to both long and short-term mating. In this study, we treated short and long-term mating orientation as two independent dimensions but maybe it would be necessary to create profiles of individuals combining their scores in both dimensions in order to better appreciate the relationships between mating strategies and status-seeking behaviors. For instance, individuals high in both short and long-term orientation may behave more dominant and prestigious than individuals low in these two dimensions.

Finally, for our fourth prediction, we tested the influence of the presence of a woman on sociosexual attitudes and status-seeking behaviors. As expected, we found that men reported higher levels of short-term mating orientation when there was a woman in the group, compared to when there was a man. In addition, we found that the presence of a woman did not affect the expression of long-term mating orientation compared to the presence of a man. These results are in line with a previous study showing that a context primed with abundance of potential mates, increases sociosexual attitudes and desires in men (Arnocky et al., 2016). However, this study employed a single-dimension sociosexual questionnaire that considers short and long-term mating orientation as the extreme poles of a continuum. Consequently, increases in sociosexual attitudes entailed an increase in short-term and a decrease in long-term mating orientation (Arnocky et al., 2016). In this study, the use of a multidimensional sociosexual inventory that considers short and long-term mating orientation as different dimensions (Jackson and Kirkpatrick, 2007) allows us to expand these previous results by showing that only one of these dimensions is affected by the presence of a potential mate. This suggests, as expected, that the presence of an unknown woman increases mating effort but specifically toward the search for short-term mating partners and that this increase is manifested intraindividually. This could be related to a strategy of maximizing reproductive success by increasing short-term mating effort in the presence of a potential mate but maintaining long-term mating effort unaffected. Our results point toward the idea that mating investments toward short-term and long-term mating can be

complementary rather than mutually exclusive strategies (Buss and Schmitt, 2019).

Regarding status-seeking behaviors and following previous studies (Slatcher et al., 2011; Tognetti et al., 2016), we expected that men in the presence of a woman should increase dominant and prestigious behaviors in order to compete for the potential mate. However, our results did not support that prediction. We found no differences in aggression when playing the PSAP in the presence of a woman compared to the presence of a man. We also failed to detect a change in the cooperativeness across the rounds of the Public Goods Game when playing with a woman compared to a man. However, men apparently were more cooperative in the third round when playing with a man compared to a woman. This last result is opposed to what we expected. A previous study suggests that contributions in a Public Good Game are affected by the courtship signaling strategy that may vary according to dispositional generosity and dominance rather than the presence of an attractive woman compared to the presence of an unattractive woman (Jensen, 2013). Our null results regarding status-seeking behaviors may indicate that individual variability in the preference of courtship signaling may influence the pathway that individuals use to gain status regardless of the context. That is, some individuals would prioritize showing generosity as a sign of courtship, while others would prioritize signs of dominance even in a context where status is gained by prestige.

This study has several limitations. First, we lack reliable measures of circulating testosterone due to the problems with the assaying salivary hormones noted in the method section, so we cannot quantitatively show the changes that the testosterone gel produced in hormone levels compared to the levels after placebo administration. However, we followed the administration protocol and waiting time described in previous studies in which administration using that protocol was seen to increase circulating testosterone levels (Carré and Olmstead, 2015). Second, due to design limitations, we were not able to measure cortisol. Previous studies suggest that levels of cortisol are important in order to detect behavioral responses caused by changes in testosterone levels (Mehta and Prasad, 2015). Third, the attractiveness of the female confederate could have varied depending on the preferences of the participants. However, we did not ask participants about the attractiveness of the confederate. Fourth, due to the pandemic outbreak, we were forced to end the data collection earlier than expected. As a result, the sample size obtained may be a limitation when detecting small effect sizes. And finally, we did not counterbalance the confederate condition and washout periods were not consistent between groups although we statistically controlled for this inconsistency. Despite this, our study has certain strengths compared to previous studies. The first one is that we manipulated the immediate social context of the participants, so they were in the presence of an actual potential mate, while the previous study used only a priming condition to obtain their results (Arnocky et al., 2016). This study also provides intra-subject evidence, while previous literature did a between-subjects comparison. This allows us to have more reliable evidence about the change that subjects experience with the administration of exogenous testosterone and in the presence of a potential mate.

In conclusion, in this study, we failed to find any evidence about the role of testosterone in calibrating sociosexual attitudes. However, the presence of a woman in the group increases sociosexual attitudes in the short-term but do not affect long-term sociosexual attitudes. That suggests that sociosexual attitudes may be expressed flexibly but that the social environment is more important than hormonal factors in this expression. We did not find evidence for the social status hypothesis suggesting that the link between changes in testosterone and status-seeking behaviors may depend on the specific context that provokes the hormonal change, as well as personality and individual traits not considered in this study.

CRediT authorship contribution statement

Pablo Polo: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Gabriela Fajardo:** Methodology, Writing – original draft, Writing – review & editing. **Jose Antonio Muñoz-Reyes:** Investigation, Methodology, Writing – review & editing. **Nohelia T. Valenzuela:** Formal analysis, Writing – review & editing. **Montserrat Belinchón:** Investigation, Writing – review & editing. **Oriana Figueroa:** Investigation, Writing – review & editing. **Ana Fernández-Martínez:** Writing – review & editing, Investigation. **Marcel Deglín:** Investigation. **Miguel Pita:** Investigation, Writing – review & editing.

Data availability

Data is available at https://osf.io/ef62y/?view_only=3d6472bd2f1144af8e15f18b19ff40c8

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