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# Testosterone and financial risk preferences

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**Abstract**

Many human behaviors, from mating to food acquisition and aggressiveness, entail some degree of risk. Testosterone, a steroid hormone, has been implicated in a wide range of such behaviors in men. However, little is known about the specific relationship between testosterone and risk preferences. In this article, we explore the relationship between prenatal and pubertal testosterone exposure, current testosterone, and financial risk preferences in men. Using a sample of 98 men, we find that risk-taking in an investment game with potential for real monetary payoffs correlates positively with salivary testosterone levels and facial masculinity, with the latter being a proxy of pubertal hormone exposure. 2D:4D, which has been proposed as a proxy for prenatal hormone exposure, did not correlate significantly with risk preferences. Although this is a study of association, the results may shed light on biological determinants of risk preferences.


*Keywords:* Testosterone; Risk; Risk-taking; Facial masculinity; 2D:4D

## 1. Introduction

Testosterone, a steroid hormone mainly produced by the testes, not only influences male reproductive physiology and development but also plays an important role in modulating male behavior (Dixson, 1998; Nelson, 2005; Wingfield, Hegner, Dufty, & Ball, 1990). The last 20 years has witnessed a surge in studies that attempt to identify relationships between circulating testosterone concentrations and social behaviors in males of many species (Adkins-Regan, 2005; Dabbs, 2000; Oliveira, 2004). For instance, testosterone has been associated with a number of behaviors in men including increased aggression (Archer, 2006), sensation seeking (see, e.g., Roberti, 2004 for a review), hostility (Hartgens & Kuipers, 2004), mate-seeking (Roney, Mahler, & Maestripieri, 2003), food acquisition (Worthman & Konner, 1987), and dominance (Mazur & Booth, 1998).[2] Adaptive explanations for the role of testosterone have been offered for its influence on each of these behaviors, but broadly speaking testosterone modulates those behaviors, which may result in increased reproductive payoffs. These behaviors entail a certain amount of risk, and the consequences can often be costly.

In mammals, testosterone exerts organizational effects on the brain early in ontogeny during sexual differentiation (Phoenix, Goy, Gerall, & Young, 1959) and again during puberty affecting male behavior in the long term (Sisk, Schulz, & Zehr, 2003). These critical periods of exposure may affect male behavior by programming how individuals respond to the activating or nonpermanent effects of testosterone. Thus, consideration of exposure during these critical periods of development, as well as current circulating

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[2] See, Wilson, Daly, and Pound (2002) for a discussion of this.

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levels of testosterone, is essential to fully understand the role testosterone has in influencing behavior.

Two studies have examined the relationship between androgen exposure and financial risk. Dreber and Hoffman (2007) found that financial risk aversion is positively correlated with 2D:4D in a sample of Caucasian men and women in Sweden but not in a heterogenous sample of American men and women in Chicago. In another recent study examining a small group of male traders in London, researchers found that, on days when participants' testosterone level was above their median level for all 8 days sampled, they made greater profits than on days when their testosterone was below their median level (Coates & Herbert, 2008). The authors attribute this higher profitability as being partly mediated by testosterone's effect on risk, although they did not examine risk-taking directly. Our study is the first study to examine the relationship between testosterone and financial risk preferences in men.

Risk preferences are defined by the trade-off between the variance and the expected value for a given resource.[3] To illustrate this, imagine that you can choose between two options, A and B. Option A entails receiving $50 with certainty, whereas option B entails a 50% chance of winning $100 and a 50% chance of winning $0. The expected outcome is the same for both options: $50. An individual is considered to be risk-neutral when displaying indifference between the two options. A risk-averse individual would prefer the certain option A and be willing to trade off some of the expected gain for a reduced risk. A risk-loving individual would prefer option B to option A. Thus, risk can be formalized by looking at the variance in the values of the possible outcomes an option implies.[4] Large individual differences in risk preferences exist, as well as robust gender differences, with men being less risk averse than women (e.g., Byrnes, Miller, & Schafer, 1999; Croson & Gneezy, In Press; Eckel & Grossman, 2002). One possible mechanism for these differences may be the regulation of testosterone. Currently, little is known about the relationship between testosterone and risk preferences.

In this study, we examine circulating levels of testosterone in men and proxies for testosterone exposure in utero and during puberty. These are 2D:4D (the ratio between the length of the second finger and the fourth ring finger) and facial masculinity. 2D:4D is thought to negatively correlate with prenatal testosterone exposure (Manning, Scutt, Wilson, & Lewis-Jones, 1998; see Hönekopp, Bartholdt, Beier, & Liebert, 2007 for review), while many masculine facial features are thought to develop during puberty under the action of testosterone (see Johnston, Hagel, Franklin, Fink, & Grammer, 2001 for review).

## 2. Methods

Ninety-eight males, ages of 18–23 years, mostly Harvard University students, participated in the study. Based on self-report, 89 subjects were heterosexuals; 7 were homosexuals; and 67% of subjects were white, 10% East Asians, 4% blacks, 4% Hispanics, and 15% "mixed or other." The experiment was approved by the Harvard University's Committee on the Use of Human Subjects in research. One outlier with testosterone levels more than three standard deviations above the mean was excluded from all analyses. 2D:4D was not calculated for 17 individuals due to unclear creases in fingers or incomplete/low-quality images of their hands. Finally, one participant was not photographed.

Testosterone levels were measured from saliva by passive drool. Saliva samples were taken from each participant upon arrival. All samples were collected between 1 p.m. and 3 p.m., and participants were asked to spit through a straw into a small polystyrene tube. All samples were collected between April 9 and June 5, 2007. No significant differences in testosterone concentrations were found between subjects as a function of the hour in which the samples were collected. Saliva samples were frozen on the same day they were supplied and stored at −20°C. At the end of the collection period, all samples were packed in dry ice and shipped via FedEx, overnight delivery, to the Human Behavioral Endocrinology Laboratory at the University of Nevada, Las Vegas, NV, USA, where they were assayed. Samples were still frozen upon arrival. Testosterone assays relied on commercially available kits (Salimetrics EIA, product number: 1-2402). Sample and standard reactions were run in duplicate, and the sample concentrations used in the analyses are the averages of the duplicates. Interassay coefficients of variation were 13.2% for low pools and 7.1% for high pools. The intrassay coefficient of variation was 6.8%.

Full frontal facial photographs were taken of all participants without glasses or head wear. Sexual dimorphism measures were taken from points marked on facial features used in previous studies (Little et al., 2008; Penton-Voak, Jones, Little, Baker, & Tiddeman, 2001). The measures taken here are identical to Little et al. (2008), and more details of the measurements, including a diagram of point placement can be found there. The identification of these features has been found to be reliable in previous studies (Grammer & Thornhill, 1994; Scheib, Gangestad, & Thornhill, 1999). In total, four sexual dimorphism measurements were taken. These were Cheekbone Prominence (ChP), Jaw Height/Lower Face Height (JH/LFH), Lower Face Height/Face Height (LFH/FH), and Face Width/Lower Face Height (FW/LFH). Each of the scores for the four different ratios was converted to a *z*-score and combined into

[3] Sensation seeking (Zuckerman, 1979) has previously been found to correlate with hormones and a range of behaviors related to risk-taking (see, e.g., Roberti, 2004 for a review). However, Eckel and Grossman (2002) find very low correlation between risk-taking measured from financial gambles, what we call risk preferences, and sensation seeking.

[4] Risk aversion is the opposite of risk loving, and is determined by the utility function's degree of concavity, implying decreasing marginal returns of utility. Utility, in turn, is a measure of an individual's preference for a good.

a single facial masculinity score ([JH/LFH+LFH/FH]−[ChP+FW/LFH]) with high scores indicating a greater degree of masculinity. These measurements have been found to be sexually dimorphic in previous studies (Little et al., 2008; Penton-Voak et al., 2001), although it is still unclear how much of dimorphism is due to variation in pubertal testosterone levels. However, testosterone during human male development facilitates the growth of bone by increasing outside bone diameter and bone mass (Vanderschueren & Bouillon, 1995). Verdonck, Gaethofs, Carels, and de Zegher (1999) found that the mandibular ramus length, upper anterior face height and total cranial base length were all significantly shorter in boys with delayed puberty as compared to controls. They also found that boys who were given low doses of testosterone showed a significantly higher growth rate of the mandibular length, ramus length and upper and total anterior face height after 1 year, as compared to untreated controls matched for height.

Participants' hands were scanned with a CanoScan LiDE70 scanner with a resolution of up to 2400×4800 color dpi. The second and fourth digits were later measured from the center of the flexion crease proximal to the palm to the top of the digit, using the Adobe Photoshop tool. The quality of some of the scans was low. When creases were unclear, we erred on the side of caution and did not use the measures thus keeping noise to a minimum. We measured in pixels to two decimals. Additional anthropometry measurements, such as height and weight, were also taken.

We measured participants' risk preferences using an investment game with real monetary payoffs adapted from Gneezy and Potters (1997). Each participant was given a balance of $250 and was asked to choose an amount, *X*, between 0 and 250 that he wished to allocate to a risky investment. The rest, $250−X, was kept by the participant. A coin flip determined the realization of the risky investment. In case of failure, the money invested was lost, and the participant had $250−X for a balance. If successful, the money invested was multiplied by 2.5, and the participant had $250+1.5× for a balance.

At the end of the experiment, one of the subjects was randomly drawn and paid according to the amount on his balance (e.g., according to the choices he made and the outcome of the coin flip). Subjects were told that there would be approximately 100 subjects participating in the study. Because investing is risky but offers higher returns, subjects must weigh a higher expected return against the risk of the investment. This means that a risk-averse individual could choose to invest $0 into the risky investment, and would thus get $250 with certainty on his balance. A risk-loving individual, could on the other hand, invest all $250 into the risky investment. He then would be equally likely to receive $0 or $625 and would in expectation get $312.50. Thus, in this risk measure, subjects do not simply choose between high and low risk; they actively have to trade off expected value against variance. We use X, the fraction invested, as our measure of risk-taking.

Regression analyses are used to examine the association between testosterone, facial masculinity and 2D:4D and risk preferences. Anthropometrics such as height and body weight, as well as age, did not correlate with risk or any of the predictors and were therefore not included as controls in the models. Sexual orientation was, however, a significant predictor of risk and was used as a control in all regressions. All regressions were run with robust standard errors.

## 3. Results

Table 1 provides descriptive statistics for each measure. Consistent with past findings, there is large individual variation in risk preferences. Self-reported age and ethnicity were not related to the risk measure or the independent variables and were not included in any of the regressions models reported below. However, sexual orientation was found to be a highly significant predictor of risk ($p<.001$, $R^2=0.078$) and was therefore used as a control in all regression analyses. Sexual orientation remained a significant predictor of risk in all regressions reported, with homosexual men being more risk-averse than heterosexual men. Mann–Whitney two-sided tests reveal that heterosexual and homosexual men do not differ in circulating testosterone ($p=.64$), facial masculinity ($p=.34$) or 2D:4D (left: $p=.28$, right: $p=.40$). Our results are based on too small a number of men who described themselves as homosexual, so although we have included them as a control in the regression analyses, we do not to attempt to interpret the results.

No relationship was found between circulating testosterone and facial masculinity ($r=.0716$, $p=.448$). There have been no studies that have yet to demonstrate a relationship between facialmetric measures of masculinity and circulating testosterone, though one study has found that composite images of men with high testosterone are perceived as more masculine than composite images of men with low testosterone (Penton-Voak & Chen, 2004). Moreover, circulating

Table 1
Summary Statistics for variables used in analyses

| Variable | All men | Heterosexual men | Homosexual men |
|---|---|---|---|
| Risk preferences (*X*) | *M*=147.47 | *M*=153.23 | *M*=75 |
| | S.D.=73.05 | S.D.=72.28 | S.D.=35.36 |
| | *n*=95 | *n*=88 | *n*=7 |
| Testosterone | *M*=99.48 | *M*=98.70 | *M*=109.38 |
| | S.D.=33.16 | S.D.=32.59 | S.D.=41.26 |
| | *n*=95 | *n*=88 | *n*=7 |
| Facial masculinity | *M*=−0.023 | *M*=−0.079 | *M*=0. 68 |
| | S.D.=2.09 | S.D.=2.07 | S.D.=2.38 |
| | *n*=94 | *n*=87 | *n*=7 |
| Left 2D:4D | *M*=.953 | *M*=0.952 | *M*=0.972 |
| | S.D.=0.031 | S.D.=0.031 | S.D.=0.043 |
| | *n*=85 | *n*=80 | *n*=5 |
| Right 2D:4D | *M*=0.953 | *M*=0.953 | *M*=0.962 |
| | S.D.=0.029 | S.D.=0.031 | S.D.=0.018 |
| | *n*=88 | *n*=82 | *n*=6 |

testosterone did not correlate with either left or right 2D:4D (left $r$=.1607, $p$=.137; right $r$=.0711, $p$=.506), nor did facial masculinity (left $r$=.0136, $p$=.901; right $r$=−.0624, $p$=.562). The fact that neither was correlated with current testosterone suggests that each are valid measures of androgenization during their respective time periods. 2D:4D has not been found to be related to current circulating hormone levels in adults (Hönekopp et al., 2007) or to facialmetric measures of masculinity (Burris, Little, & Nelson, 2007).

Fig. 1 shows the positive relationship between risk and testosterone, and Fig. 2 shows the positive relationship between risk and facial masculinity, both when adjusting for sexual orientation. Running ordinary least squares (OLS) regressions and controlling for sexual orientation, a highly significant effect of circulating testosterone on risk preferences is found (β=.26, $R^2$=.15, $p$=.004). That is, men with higher testosterone levels are more risk-taking in an investment game. We also find that the group of men that invested all $250 have significantly higher testosterone ($M$=115.9) than with those that invested less ($M$=92.6) (Wilcoxon rank sum, controlling for sexual orientation: $p$=.0061). Moreover, we find a significant effect of facial masculinity on risk preferences such that men with more masculinized facial features are more likely to make riskier financial decisions (β=.29, $R^2$=.17, $p$=.002). When included in the model together, both circulating testosterone (β=.24, $p$=.005) and facial masculinity (β=.27, $p$=.003) remain highly significant predictors of risk and together explain 22% of the variation in risk, when also controlling for sexual orientation.

Since the risk measure is a censored variable where participants cannot invest more than $250, we also run a tobit regression. The results are qualitatively similar to those from the OLS reported above. The coefficients on the relevant variables, testosterone (β=.36, $p$=.006) and facial masculinity (β=.35, $p$=.002) are bigger, and the $p$ values, similar.

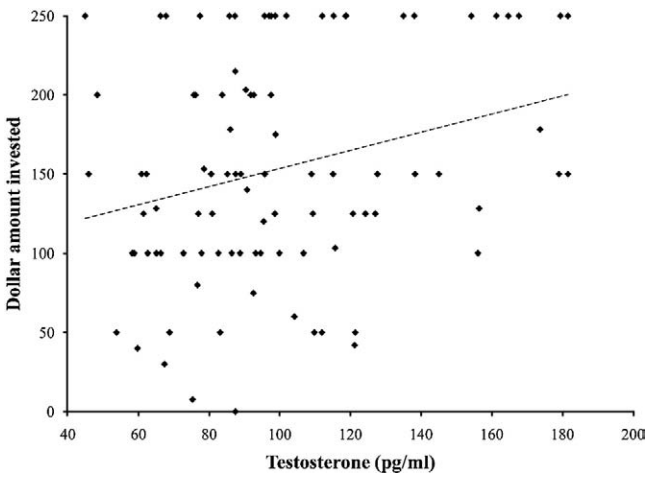


Fig. 1. Risk preferences (dollar amount invested) plotted against testosterone (pg/ml) for all men, adjusted for sexual orientation.

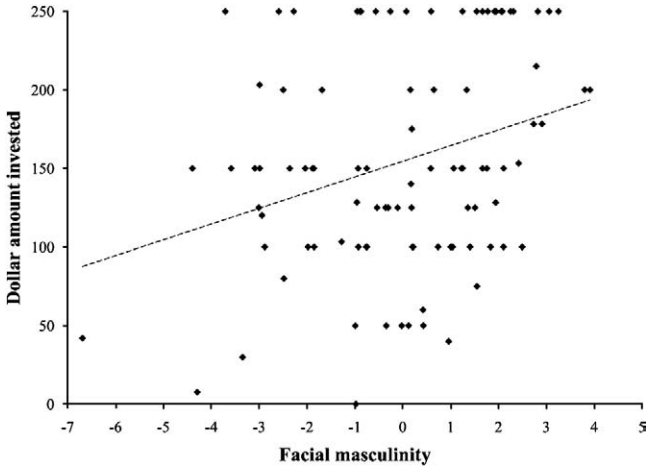


Fig. 2. Risk preferences (dollar amount invested) plotted against facial masculinity for all men, adjusted for sexual orientation.

These effects demonstrate economic significance. When controlling for both salivary testosterone and facial masculinity, a man with a testosterone level one standard deviation above the mean invests $17 more (out of a possible $250) than the average man into the risky investment, while a man with a facial masculinity score one standard deviation higher than the mean invests $9 more than the average man.

Neither left hand nor right hand 2D:4D are significantly correlated with risk preferences (left hand $p$=.29, right hand $p$=.44), and when controlling for salivary testosterone and/or facial masculinity the $p$ values increase.

## 4. Discussion

The findings of this study suggest an association between activational effects of testosterone and, possibly, its organizational effects during puberty and behaviors related to risk-taking in men. Men with higher levels of circulating testosterone and masculine faces are more likely to make risky financial decisions. There was no evidence in this study that 2D:4D is related to risk in men. However, the null result for 2D:4D may be due to the small and ethnically heterogeneous sample.

Monetary transactions are a recent phenomenon in human history, but the acquisition and accumulation of resources by men is not. Money is, in this sense, a proximal currency used to maximize returns in some other currency, such as utility or fitness (Daly & Wilson, 2002). Men may have evolved to engage in riskier behaviors compared to women because the potential returns in terms of fitness payoffs can be higher. A woman's reproductive success is limited by the number of offspring she can produce whereas in men it is limited by the number of partners he can attract. Increased resources in men may translate into both increased mating opportunities and increased child survivorship. Indeed, studies have found that women find wealth to be an attractive quality when choosing a mate and value it more than men do in potential mates

(Buss, 1989; Hitsch, Hortacsu, & Ariely, 2006). Therefore, there may have been increased selection pressure on men to maximize resource acquisition in order to attract members of the opposite sex.

We suggest that one possible way for a man to increase his resources relative to other men would be to engage in risky financial investments with the possibility of lucrative monetary returns. Since men differ in the degree to which they are willing to trade off expected value against variance, they will also differ in their resulting financial payoffs. Having greater financial payoffs can result in greater access to resources and, thus, greater ability to attract women. Potentially, financial risk-taking might be comparable to other risky male behaviors associated with reproduction. For example, males of many species engage in direct male–male competition over both resources and mates, and this behavior is often activated by testosterone during the breeding season (Balthazart, 1983; Harding, 1981). In light of financial risk being a potential form of male–male competition, there are clear reasons to expect that men with higher levels of circulating testosterone would be more economically risky as evidenced by our study.

The role of environmental condition in early life and puberty on life history trajectories is becoming increasingly understood. Many traits, both physiological and behavioral, including those defined as male-typical traits, are contingent on environmental input throughout development and adulthood. For instance, dominance status and aggression in some species during adulthood is reduced when condition in early life is poor (Royle, Lindström, & Metcalfe, 2005). 2D:4D, which is thought to not only correlate negatively with prenatal testosterone exposure but has also been found to correlate negatively with high amniotic testosterone-to-estradiol ratio (Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning, 2004), has been found to negatively correlate with competitiveness and performance in sports (Hönekopp, Manning, & Müller, 2006; Manning & Taylor, 2001). Additionally, Dreber and Hoffman (2007), using the same risk task used in this study, find that risk aversion is positively correlated with 2D:4D in a sample of Caucasian men and women in Sweden. They also find that the sex difference in risk preferences is diminished when 2D:4D is included as a control in their regression model. However, when examining the same relationship using a more ethnically heterogeneous sample from Chicago of both men and women, they do not find a relationship between 2D:4D and risk. Likewise, the results of this study, which also utilize a diverse sample, did not find a relationship between 2D:4D and risk preferences. Since differences in 2D:4D exist between different ethnic populations (Manning, Stewart, Bundred, & Trivers, 2004), the relationship may hold only in homogenous samples. In terms of optimizing risk-taking, it is also plausible that decisions may be modified more by acute signals, such as circulating testosterone, based on current environment and condition. Biological influences early in life could play a role, but their effects may be smaller. If the effect is small, it may not have been detected due to the small sample and possible measurement error associated with calculating 2D:4D.

Why facial masculinity should predict economic behavior is less obvious than that of current testosterone. It may be that pubertal levels of testosterone have organizational effects on the brain rendering those with higher levels of exposure more risky. The immuncompetence handicap hypothesis states that masculine traits which develop under exposure to testosterone may signal good genes, since testosterone is thought to suppress the immune system (Folstad & Karter, 1992). Indeed, facial masculinity in adolescent boys was found to be correlated with both actual and perceived health (Rhodes, Chan, Zebrowitz, & Simmons, 2003; but see Boothroyd et al., 2005) and hand grip strength in male college students was found to be correlated with their ratings of facial masculinity by women (Fink, Neave, & Seydel, 2007). Therefore, individuals with more masculinized features and higher testosterone may be of higher quality and thus, more likely to take risks because 1) they are used to performing well in a wide range of tasks, and 2) because they are better able to absorb the costs if the outcomes of such risky actions are poor. Thus, androgen exposure may not directly regulate risk preferences but may instead represent markers of health and genetic fitness which in turn shapes risk preferences.

It is also plausible that a reciprocal relationship between phenotypic appearance and environment exists so that masculine men take more risks not only because they are expected to, but also because they are expected to succeed. That is, others may perceive masculine individuals as more likely to succeed when engaging in risky behaviors. Such perceptions by conspecifics may not only skew individuals' self-perceived level of risk but may also affect the actual outcomes of certain risky behaviors. Thus, pubertal testosterone exposure could shape lifelong risk perceptions directly through androgenization of the brain or indirectly through masculinization of the face which, in turn, affects how individuals act and react in their environment.

This is the first study to specifically examine an association between testosterone exposure and financial risk preferences, though a few studies have attempted to examine the hormonal underpinnings of other economic behavior. For example, Chen, Katuscak, and Ozdenoren (2005) find that women in the menstrual phase of their cycle, when estrogen and progesterone are low, are more risk-taking during bid in a first price auction (the person with the highest bids "wins" the auction), whereas during other phases of the menstrual cycle, they are more risk averse. In a study on day traders, Coates and Herbert (2008) find higher testosterone levels on days when traders made above average profits. Burnham (2007) examined the role of testosterone in men's performance in the ultimatum game, a negotiation game where a proposer makes an offer of how to allocate money between himself and a responder. The responder, in turn, either accepts or rejects the offer, with the resulting

outcome of zero payoffs for both parties if the responder rejects. While high- and low-testosterone men gave similar offers, high-testosterone men were more likely to reject selfish offers. The fact that high-testosterone men were more likely to reject unfair offers and receive no economic benefits suggest that they perceive low offers as challenges and may be more concerned with maintaining their reputations and increasing the likelihood that future interactions, if they occur, will be more economically favorable (Burnham, 2007). In an interesting study, Cesarini, Dawes, Johannesson, Lichtenstein, and Wallace (In Press) use a classical twin design to demonstrate that risk preferences elicited experimentally are heritable. Since circulating testosterone levels are under moderate to strong genetic influences (Harris, Vernon, & Boomsma, 1998; Ring et al., 2005), our findings suggest a possible hormonal pathway through which genetic transmission of risk may operate, though such a conclusion necessitates continued research.

There are a number of limitations with this study. First, this is a test of association where subjects were tested on only 1 day. We therefore cannot make any claims about causality nor can we discuss the salivary testosterone measures as reflecting stable, trait-level values or current state-level values. Further work should examine whether natural intraindividual variation in testosterone predicts financial risk as well as examine the effects of exogenously administered testosterone to determine causality. Moreover, this study mainly consisted of Harvard students, and we did not control for variation in socioeconomic status. We suggest future work include more diverse sets of participants where the effects of socioeconomic status can be examined.

Given the scant literature in the field of biological economics, this study may afford some important insights into the biology of economic risk preferences. This is the first study to examine the relationship between both activational and organizational effects of testosterone and economic behavior. Men with testosterone levels that were one standard deviation above the mean invested almost 12% more of their portfolio in a risky financial game compared to men with average testosterone levels. Likewise, men with sexually dimorphic facial features invested more in financial risks. Having masculinized facial features one standard deviation above the mean translated into more than 6% higher monetary investments than men with average masculinity features. Insofar as laboratory findings generalize to higher stakes, these biological influences could potentially have a significant impact on the economic welfare of given individuals. Given the important welfare consequences associated with financial investments, understanding the biological mechanisms that mediate such choices is of utmost importance.

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