



Decision-making, financial risk aversion, and behavioral biases: The role of testosterone and stress

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ABSTRACT

We examine the relation between testosterone, cortisol, and financial decisions in a sample of naïve investors. We find that testosterone level is positively related to excess risk-taking, whereas cortisol level is negatively related to excess risk-taking (correlation coefficient [r]: 0.75 and -0.21 , respectively). Additionally, we find support for the dual-hormone hypothesis in a financial context. Specifically, the testosterone-to-cortisol ratio is significantly related to loss aversion. Individuals with a higher ratio are 3.4 times more likely to sell losing stocks (standard error [SE]: 1.63). Furthermore, we find a positive feedback loop between financial success, testosterone, and cortisol. Specifically, financial success is significantly related to higher post-trial testosterone and cortisol by a factor of 0.53 (SE: 0.14). Finally, we find that in a competitive environment, testosterone level increases significantly, leading to greater risk-taking than in noncompetitive environment. Overall, this study underscores the importance of the endocrine system on financial decision-making. The results of this study are relevant to a broad audience, including investors looking to optimize financial performance, industry human resources, market regulators, and researchers.

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1. Introduction

To what extent does physiology impact financial decision-making? Specifically, how do hormones in general, and the interplay between testosterone and cortisol, affect financial decisions? Finance professionals and academics alike have typically ignored these questions. This study helps to answer these questions from an endocrinology perspective. Specifically, we examine the relation between the sex hormone testosterone and the stress hormone cortisol on investment decision-making.¹ The current body of research (summarized below) suggests that these hormones cross the blood-brain barrier and play a key role in brain areas involving risk and reward. Specifically, testosterone is thought to exert a significant influence on cognitive processes dealing with stimuli interpretation, risky behavior, and confidence

(Coates et al., 2010). Therefore, it is thought that testosterone impacts financial decisions and outcomes. However, few studies exist about the relation of testosterone and financial decisions, and their results are inconclusive (Apicella et al., 2015). Similarly, medical studies show that cortisol plays a key role in brain areas associated with risk and reward. Since it is widely held that stress is rampant among finance professionals, such as traders and fund managers (Kahn and Cooper, 1990; Jones et al., 2003; Oberlechner and Nimgade, 2005), it is likely that cortisol, like testosterone, have a significant influence on financial decisions and outcomes (i.e., McEwen and Sapolsky, 1995; Sapolsky, 1996; Dominique et al., 1998; Lupien et al., 2009). Unfortunately, studies about the role of stress on financial choices and outcomes are scant, and the evidence so far is inconclusive.

The dual-hormone hypothesis postulates that cortisol regulates the effects of testosterone on behavior. For example, high testosterone level in tandem with low cortisol level is associated with a biological predisposition for social aggression, presumably by suppressing cortical and subcortical neural communications that control socially aggressive tendencies (i.e., Van Honk et al., 2010). More broadly, imbalance in the ratio of testosterone-to-cortisol is associated with social aggression (Terburg et al., 2009), social dominance (Mehta and Josephs, 2010), anger (Hermans

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¹ Cortisol is released into the blood by the adrenal glands in response to stressful stimuli. Therefore, the circulating level of cortisol (versus cortisol that is stored in the adrenal glands) is the primary biological marker of stress. In this study we use these terms interchangeably.

et al., 2008) and a plethora of other social risky behaviors (Barel et al., 2017). Mehta et al. (2015) use the Balloon Analog Risk Task to study the dual-hormone hypothesis in an economic setting. Specifically, participants earn money for every time they decide to add increasing amount of air into a balloon. When a random threshold is met, the balloon explodes, and participants lose all the money made until that point. The authors find that testosterone level is positively related to increased risk-taking (i.e., pumping greater amount of air into the balloon), but only when cortisol level is low. Overall, the literature suggests that the dual-hormone hypothesis may apply in economic settings. To our knowledge, we are the first to study the dual-hormone hypothesis in a financial setting, specifically, during investment tasks.

The present study represents one of the first comprehensive efforts to understand the isolated and combined role of testosterone and cortisol on investment decisions and outcomes. Given the nascent state of the literature, it is still unknown whether testosterone, stress, or their interaction influence every kind of financial task (i.e., long-term investing, day-trading, and gambling), or if said influence is only present during certain conditions, such as a competitive environment (Schipper, 2014). The related literature suggests that cognitive biases lead to irrational choices that can affect financial performance, such as low portfolio diversification (French and Poterba, 1993), overconfidence (Barber and Odean, 2000) and the disposition effect (Dhar and Zhu, 2006). Additionally, the literature suggests that testosterone and cortisol modulate cognitive biases and may influence financial decision-making by shifting economic utility functions, confidence levels, and/or risk preferences, through their effect on the brain's nucleus accumbens. As a part of the dopamine system, the nucleus accumbens is associated with pleasure and irrational risk-seeking behavior (Kuhnen and Knutson, 2005).² For example, evidence of the “rewarding” property of testosterone is found in addiction studies of humans taking anabolic steroids (Kashkin and Kleber, 1989). This rewarding property is thought to be due to the effects of testosterone and its two metabolic byproducts (dihydrotestosterone (DHT) and estradiol) on the nucleus accumbens, causing an increase in dopamine release (Frye et al., 2002). Overall, the relation between testosterone, cortisol and affect suggests that these hormones may modulate financial cognitive errors, given that many economic biases involve emotions (Yuen and Lee, 2003; Lerner et al., 2004; Nofsinger, 2005). In this study we treat the above suggestions as hypotheses, and examine the nature of the relation between testosterone, cortisol, and financial decisions and outcomes. The question of *how* testosterone and cortisol influence financial decision-making is perhaps one of the most difficult questions in this line of research because it involves understanding the biochemical mechanism of hormonal action in the brain. However, this study addresses the question from a behavioral perspective, linking hormone level to observable financial decisions and the resulting outcomes.

Few studies have examined the link between testosterone (Coates and Herbert, 2008) and cortisol (Coates et al., 2010) and investment decision-making. Said studies provide a benchmark for comparison. However, our study differs from those papers in the following key respects: First, we analyze the relation of testosterone and cortisol in tandem (i.e., the dual-hormone hypothesis) and in isolation due to cortisol's influence on testosterone. Second, we

² Dopamine is the major neurotransmitter of the reward system of the brain, which includes the ventral tegmental area, the nucleus accumbens, the amygdala, the hippocampus, and the medial prefrontal cortex. Rewarding experiences such as food, sex, and drugs lead to the release of dopamine, providing feelings of enjoyment and motivating the reinforcement of these activities. Bressan and Crippa (2005) provide a basic review of the dopamine system and its role in reward and pleasure.

examine the relationship between testosterone, cortisol, and financial decisions made under non-competitive and competitive environments. Third, we use a sample of male and female naïve investors, whereas the aforementioned papers employ a small sample of male professional traders. As such, the results of the present study have a more straight-forward application to a broader range of investors. Fourth, this study is free of trader selection bias, as we do not exclude subjects based on their trading skills or lack thereof. Such bias occurs in Coates and Herbert (2008) and Coates et al. (2010) because traders are typically pre-screened prior to being hired, or let go if they prove unsuccessful.³ Finally, we examine the potential feedback loop between performance and hormone level. It has been suggested by other studies that certain economic tasks, such as poker tournaments, may impact physiological processes (Steiner et al., 2010). We aim to show that said feedback exists even in naïve traders, which is akin to showing a link from the stock market back to investor. Such feedback mechanism would be a critical component of feedback models of stock market bubbles, yet little research has been conducted in this regard.

In this study, we investigate the role of testosterone, cortisol, and the dual-hormone hypothesis on financial choices and outcomes during two single-decision points, portfolio formation (asset allocation) tasks, and one multi-point portfolio rebalancing task. These tasks are akin to long-term investing in practice, because (as explained below) we make use of realistic financial trading simulation software. We find that higher levels of testosterone increase financial risk-taking, whereas higher levels of stress decrease financial risk-taking and portfolio expected returns. Additionally, cortisol is negatively related to portfolio diversification, which translates into greater exposure to unsystematic risk. Therefore, the positive relation between testosterone and risk-taking in social settings (i.e., social decisions) seems to be lacking in financial decisions, presumably due to the significant effects of cortisol levels. To this end, the results show that higher testosterone levels coupled with lower cortisol levels influence the selection of portfolio risk. Specifically, subjects undertake greater risk than necessary in order to meet the desired investment goal, not just to achieve a minimum required rate of return, but purposely done in order to perform significantly better than their peers. These results are consistent with the dual-hormone hypothesis that testosterone is only associated with increased financial risk-taking when cortisol levels are low. The results also show that subjects with higher testosterone to cortisol ratios are more likely to sell losing stocks, showing that the dual hormone hypothesis plays an important role in investment biases, especially the disposition effect. Finally, our results support the hypothesis that a feedback loop exists between financial decision-making and hormone activity. Specifically, we find that testosterone levels rise significantly in subjects who outperform their peers. Pre-trial levels of testosterone and cortisol influence financial decisions. In turn, the outcome of said decisions impact post-trial hormone levels, which influence future financial decisions. As such, our results show that economic models of asset valuation should consider the dynamic relation that exists between endocrine processes and financial decisions.

The remainder of this paper is organized as follows. Section 2 reviews the literature on the influence of testosterone and cortisol on financial decision-making. Section 3 describes our methodology and experiment. Specifically, we discuss our subjects, the trials or tasks, investment simulations, and saliva testing. Section 4 reviews the results for the first asset allocation task. The results

³ It is common practice to put applicants through trading simulations and trial periods before hiring them as traders.

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