Received: 14 February 2020 | Revised: 31 May 2020 | Accepted: 09 June 2020
DOI: 10.22034/ecc.2020.110292
Eurasian Chemical Communications SAMI

FULL PAPER

Chemistry of financial behaviors: a mini review of hormones effect on financial behaviors (2010-2019)

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Financial behaviors such as risk-taking highly depend on brain function. On the other hand, the brain is affected by various physiological, biological, environmental, genetic, and other related factors. One of the important factors that overshadow financial behavior is the chemistry and biochemistry of the brain, which the effect of hormones on brain function falls within this area. Hormones are chemicals with receptors all over the body including brain, which affect risk taking behavior, assessment, attitude and other factors which lead to changes in decision making. In the last three decades, researchers in financial science, economics, neuroscience, neuroeconomics, and other fields have examined the effects of various biological factors including hormones and neurotransmitters on decision making, risk attitude, risk assessment, both in humans and other animals to find experimental results for assessing the relation of biological factors and financial behaviors. The present study reviews some of the most important studies conducted in the recent decade on the period of 2010-2019 concerning the chemical effects of the two hormones of testosterone and cortisol on people financial behavior.

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KEYWORDS

Chemical hormones; neuroeconomic; financial behaviors; testosterone, cortisol, risk aversion.

Introduction

In the past, economic studies were based on the assumption that human is a creature with rational decisions [1], but over time, and especially over the past thirty years, it has been proven that previous assumptions could not explain many financial behaviors. Hence, researchers in various science fields have tried to explain the reasons for these issues by using various theories and experiments. Today, based on experimental studies, it has become clear that financial behaviors, such as risk-taking, like other human behaviors, are rooted in various environmental, cultural, genetic, biochemical, and other related areas that affect brain chemistry and thus its function. Economic risk-taking can be defined by the difference between the variance and the expected price of a financial resource. From an economic point of view, individuals are divided into three groups, including indifferent to risk, risk-taking, and risk-averse. The reasons for adopting different risk-related approach by people are one of the topics that have attracted the attention of researchers in various sciences and various methods of psychology and biology have been used to provide a complete scientific perspective on this issue. Some studies have tried to link individual risk-taking to psychological variables such as mental states and emotions.

Some researchers have linked risk-taking to biological variables such as gene polymorphism and brain activity. In recent decades, the view that risk-taking, also the focus of this study, is strongly influenced by hormones has been strongly supported and has resulted in many empirical studies [2]. From a biological point of view, hormones are one of the most important factors influencing brain function and, consequently, financial behavior. Hormones are chemicals that circulate in body fluids such as blood and regulate the body's physiological activity by influencing target organs. Hormone secretion is controlled by the brain in various organs, but many of these hormones also have receptors in the brain itself, thus affecting the activity of the nervous system [3]. According to various neurological studies, it seems to be natural that changes in the nervous system caused by chemical changes in the brain cause changes in people mental states and behaviors. Neurotransmitters, with their different mechanisms, have a similar effect on hormones of individuals and affect them both physically and mentally.

Concerning the effect on financial behaviors, several studies have been conducted on hormones and neurotransmitters, such as testosterone, progesterone, oxytocin, cortisol, norepinephrine, dopamine, serotonin, etc. The effect of the two hormones of testosterone and cortisol on financial behavior has been extensively and frequently studied in many behavioral financial, neuro-economic, and behavioral economic studies, indicating the importance of these two hormones on financial behavior. Testosterone is a steroid hormone that plays a key role in the development of masculine physical traits and sexual function and is associated with antisocial behavior and violence in humans and other animals [4]. Testosterone is a gonadal hormone secreted in both men and women, and with receptors throughout the body; it not only affects neuroanatomical and physiological changes, but also affects the behavior of mammals, including humans [5]. Cortisol, as the main glucocorticoid (a group of steroids secreted by the adrenal cortex), is produced in the adrenal and regulated by the hypothalamic–pituitary–adrenal (HPA) [6]. This hormone is one of the most important components of responding to stress and coping with unforeseen events and threats that also affect financial decision making [7].

As levels of these two hormones are well measurable and variable, they have been the subject of many studies on financial behavior. In studies conducted in this regard, the levels of these two hormones have been measured by different methods such as blood test, saliva sample and immunosuppression methods. To change the level of testosterone and cortisol in the body, different methods have been tested, including the use of topical gels, pills, exposing people to stressful situations and increasing hormone levels via stimulating ambitious behaviors with various psychological tests and then measuring changes in financial behaviors resulting from these changes. Results of these studies are the main subject of the current study.

The above-mentioned points reflect the important effects of testosterone and cortisol on people financial behaviour. Various factors affect the change in hormone levels in humans, which ultimately affect people’s financial behaviour. Moreover, financial behaviours have a significant impact on the economic and social conditions of people. Considering the importance of the above-mentioned issue, the current article reviews the studies conducted on the relationship between the chemical effects of these two hormones and financial behaviours between the years 2019 and 2010. In the next section, the studies related to the current research subject are reviewed separately for the type of hormone and increasing trend. The last section also presents the discussion and conclusions and recommendations for future studies.

Testosterone

Testosterone is a gonadal hormone produced in both men and women and has receptors all over the body. Seasonally daily and even hourly changes in the level of testosterone generate a diurnal cycle with a maximum at early morning which decrees during the day [8]. This hormone plays a crucial act in sexual function and body masculinization. Antisocial and aggressive treatment in both non-humans and humans is widely related to testosterone [9]. In medicine, testosterone is broadly discussed in relation to physical development, puberty, fertility, and pathology. The association between changing mood, aggression, sexuality, and financial behaviors have been reported. In addition to mutual relation with aggressive behaviors, gonadal hormones are related to competition, spatial tasks, memory, sensation seeking scales, and risk preferences.

Cortisol

Cortisol, the main human glucocorticoid, is produced and regulated by the hypothalamic–pituitary–adrenal (HPA) axis. This axis is critical to maintaining normal physiological homeostasis, and it regulates diverse processes, including metabolism, cardiovascular biology, immune function/inflammatory responses and cognitive function. Corticotrophin-releasing hormone (CRH) is produced by neurons in the paraventricular nucleus of the hypothalamus, which project to the base of the hypothalamus, the median eminence. In response to a stressful stimulus, CRH is released from axon terminals into the hypothalamic– pituitary portal circulation, and reaches the anterior pituitary where it promotes the synthesis and secretion of adrenocorticotropic hormone (ACTH) by pituitary corticotrophs. ACTH then travels through the bloodstream to reach the adrenal glands (situated bilaterally above the kidneys) where it stimulates the synthesis and release of adrenal glucocorticoid hormones and adrenal androgens [10].

Testosterone and Cortisol Biosynthesis

The pathways for synthesis of progesterone and mineralocorticoids (aldosterone), glucocorticoids (cortisol) and androgens (testosterone) are arranged from left to right. The enzymatic activities catalyzing each bioconversion are written in boxes. For those activities mediated by specific cytochromes P450, the systematic name of the enzyme ('CYP' followed by a number) is listed in parentheses. CYP11B2 and CYP17 have multiple activities. The planar structures of cholesterol, aldosterone, cortisol and testosterone are placed near the corresponding labels. Deficient 21-hydroxylase activity prevents synthesis of aldosterone and cortisol and shunts precursors such as 17-hydroxypregnenolone into the pathway for androgen biosynthesis.

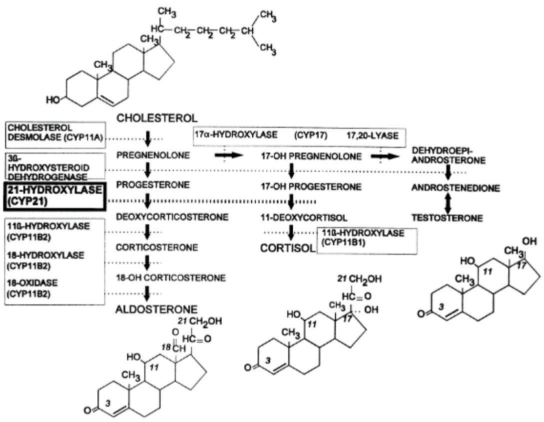

FIGURE 1 Pathways of steroid biosynthesis in the adrenal cortex [11]

Testosterone and financial behaviors

In a detailed review, Coates *et al.* (2010) discussed the lack of studies done about the association between endocrine system and financial decision-making. They ran a study on the cognitive effects of steroid hormones and their probable connection to trader performance in the financial markets. According to the study, previous research has proposed that cortisol is related to risk and testosterone to reward while chronic and acute exposure to these hormones leads to different cognitive effect; acute and chronical rises cause optimized performance on a range of tasks and boosted irrational risk-reward choices, respectively. Accordingly, they provided the hypothesis that the steroid hormones may mediate irrational exuberance and pessimism during market bubbles and crashes. They also suggested that if market movements are magnified with hormones, then market instability may be affected by the age and sex composition among traders and asset managers. The survey suggested that traders with high level of testosterone among different facts just pay attention to opportunities, while the same traders in the case of chronic rise of cortisol only look for risk. The survey also connected instability of risk preference to hormonal changes in a way that increasing testosterone may boost risk appetite in bull markets while cortisol rising may lead to lesser risk appetite during a bear market. Based on the findings, they concluded that if hormones affect risk-taking, financial markets may be more stable with a greater endocrine diversity in the financial industry through diversity in sex and age of market participants [12]. In a study on the effect of power posing on risk tolerance, Carney *et al.* (2010) explained that in all animals including humans, power expression is through open, expansive postures, and powerlessness is expressed through closed, contractive postures; therefore, they put forth this hypothesis that these postures may really lead to power. Based on the results, posing in high-power nonverbal displays may lead to neuroendocrine and behavioral changes for both male and female: participants posed to high-power experienced testosterone rising, decrease in cortisol, and as a result more feelings of power and risk-tolerance; low-power posers demonstrated the opposite pattern. Briefly, they claimed that posing in displays of power give rise to beneficial and adaptive psychological, physiological, and behavioral changes. A group of studies evaluated the effects of more than one hormone on human behaviors [13].

In an attempt to discover the effect of testosterone on risk taking, Stanton et al. (2011) addressed the relationship between endogenous testosterone and economic preferences in 298 men and women participants and found a significant correlation between endogenous testosterone levels and risk and ambiguity preferences in individuals, but not loss aversion. Based on the results they reported that with a high similarity in both men and women, low or high levels of testosterone (more than 1.5 *SD* from the mean for their gender) lead to risk and ambiguity neutrality, whereas intermediate levels of testosterone cause risk and ambiguity aversion. This relationship was highly similar in men and women [14]. In a more extended study, Branas-Garza & Rustichini (2011) examined the effect of testosterone on performance in financial activities in two hypotheses: The effect of testosterone on risk attitude versus a complex effect involving risk attitude, and the effect of the hormone on reasoning ability. They gathered data on the three variables in a sample of 188 college students all from Caucasians ethnicity. They measured 2D: 4D digit ratio, abstract reasoning ability with the Raven Progressive Matrices task, and risk attitude with choosing among lotteries. Low digit ratio in male participants was related to higher risk taking and higher grade in abstract reasoning ability when utilizing a mixed measure of risk aversion for different tasks which illustrates the higher performance and higher survival rate in traders, also the correlation between abstract reasoning ability and risk taking. They analyzed that how much of the total effect of digit ratio on risk attitude is direct, and how much is mediated and reported that a big portion of the testosterone effect on risk attitude is mediated by abstract reasoning ability [15]. Macks *et al.* (2011) hypothesized that risk preference is related to pubertal maturation, where there is interplay between gonadal hormones, the neural mechanisms that underlie affective processing, and risky behavior. To test this hypothesis, they asked 50 adolescents containing 33 girls and 17 boys in the age of 10 to 16 at different stages of puberty to perform a gambling task lying in the MRI scanner, where saliva samples for hormone evaluation were collected. Based on the results, Gonadal hormone levels were correlated with the neural reaction to a monetary reward obtaining and testosterone level was determined correlated with activation in the striatum for boys and girls positively, indicating the relation of individual differences at puberty period and the way adolescents responded to reward, which can affect risk-taking behavior conclusively [16].

Hormones have crucial effects on human behavior and attitudes. Wibral *et al.* (2012), considering lying as a universal phenomenon with significant social and economic implications, studied a possible hormonal influence, focusing on the testosterone, which has been reported to play an important role in social behavior. In a double-blind placebo-controlled study, they invited 91 male participants to take a transdermal administration of 50 mg of testosterone. Individuals were asked to participant in a task, in which their payoff depended on the self-reported outcome of a die-roll. Subjects could increase their payoff by lying without fear of being caught. The results showed that testosterone administration greatly decreased lying in men. Self-serving lying occurred in both groups, however, reported payoffs were significantly lower in the testosterone group. Gender differences in Risk Taking is constantly related to many economic subjects [17]. Charnessa and Gneezyb (2012) collected the data from 15 sets of investigations based on one investment game. They noticed that most of the previous examinations were not aimed to assess gender differences and were done by different researchers in different countries, with different instructions, durations, payments, subject pools, etc. The authors collected the data from the same basic investment game to test the robustness of the findings and consistently reported that women invest less, thus seem to be more risk averse than men in financial tasks [18].

Apicella *et al.* (2013) attempted to influence testosterone in men through having them win or lose money against another male in a chance-based competition. They employed two treatments where they varied the amount of bet money to directly compare winners to losers who earned the same amount, thereby abstracting from income effects. The study found that men experiencing an increase in bioactive testosterone took on more risk, the association which remained when controlling for whether the participant won the competition, whether subjects won the competition did not predict future risk. They concluded that change in testosterone, and thus individual differences in testosterone reactivity, rather than the act of winning or losing, influenced financial risk-taking. Some studies related risk taking not only to hormones but also to human brain areas [19]. Exploring the effect of puberty on the risk taking development, Peper *et al.* (2013) used a psycho-endocrine neuroimaging procedure to examine the contribution of testosterone levels and OFC (Orbitofrontal cortex) -a brain region that is thought to modulate the relation between testosterone and risk taking- morphology to individual differences in risk taking, in a normative sample of 268 participants between 8 and 25. Using the balloon analogue risk-taking task to measure risk taking, they found that, related to age, higher endogenous level of testosterone was related to increased risk taking in boys (more explosions) and girls (more money earned). In addition, they reported a smaller medial OFC volume in boys and larger OFC surface area in girls related to more risk taking. A mediation analysis indicated that irrespective of age, OFC morphology relatively mediates the association between testosterone level and risk taking in such a way that a smaller medial OFC in boys increases the association between testosterone and risk taking but represses the association in girls. Although behaviors intended to gain high social status are commonly characterized as aggressive and competitive, it is clear that high social status achievement is not only through antisocial behavior but also through prosocial behavior [20].

Psychological tasks have always been helpful indicators of human attitudes. Evans and Hampson (2014) hypothesized that compared with men having low level of testosterone, men with higher testosterone would perform more poorly on the Iowa Gambling Task (IGT), a common task to assesses decision-making. They also predicted that the effect of testosterone on risk-taking tendency would mediate the effect. As the sample, IGT was completed by 61 healthy adult males. Current level of testosterone and its level during early development were respectively measured by saliva sample and 2D:4D digit ratio. According to their work, men with high testosterone levels chose fewer cards from the advantageous decks on the IGT. Financial risk-taking, measured by the Jackson Personality Inventory (a psychological test for measuring adroitness), was negatively correlated with the number of good card selections. Based on the results, it was reported that risk-taking significantly meditates the association between IGT and 2D:4D ratio. The research also concluded that an organizational effect of androgens during early development may positively affect adult IGT performance through an influence on take risks appetite [21]. Zilioli and Watson (2014) designed their study considering that testosterone tolerance is associated with outcome-dependent changes in social status, such as the Winner Effect (defined as the increased probability of winning an aggressive encounter following previous victories). They collected salivary testosterone from pairs of men participants engaging, on two days in a row, in head-to-head competitions on a previously validated laboratory task. In accordance with the competition effect, testosterone reactivity on the first day, predicted the task performance on the second day. Further, those participants that lost in both days experienced the most decline in testosterone compared to those who lost the second day but won the first day. Considering the type of status hierarchy (stable and unstable) that emerged as a result of the combined outcomes of the two competitions, on the second day testosterone changes were also analyzed. In congruence with the Challenge Hypothesis (the idea that testosterone rise occurs in response to a challenge (i.e. losing the high-status rank obtained after the first competition) thus encouraging further attempts at regaining status (Mehta and Josephs, 2006).), males who won one day and lost the other one (in unstable hierarchies) experienced an increase in testosterone compared to men who won or lost both days (in the stable hierarchies). Results are discussed within a comparative perspective, drawing parallels with the Winner Effect and the Challenge Hypothesis observed in non-human animals [22].

Considering adolescence as an increasing risk-taking period, based on overactivity of the reward system in the brain, Braams *et al.* (2015) established a study with two main goals: To test age-related changes patterns of the nucleus accumbens activity relating to changes in puberty, laboratory risk-taking and self-reported risk-taking attempt; and to test whether differences in pubertal progress and risk-taking behavior were contributors to longitudinal change in nucleus accumbens activity. They had 299 and 254 participants respectively at the first and second time point, ranging between 8 –27 years old, and time points were separated by a 2 years interval. At both time points, neural reaction to rewards, pubertal development, laboratory risk-taking, and self-reported risk-taking were collected. They reported that Nucleus accumbens activity change was related to change in testosterone and self-reported reward-sensitivity. Thus, this longitudinal analysis provides new insight in risk-taking and reward sensitivity in adolescence. Their work provides two insights in adolescence risk taking. First, they confirmed an adolescence maximum level in nucleus accumbens activity, and secondly, they emphasized crucial role of pubertal hormones same as testosterone in risk-taking tendency. Instability of financial markets has always been a controversial topic but it always has been interesting that how and why these disasters happen [23]. Cueva *et al.* (2015) focused on the theory that endogenous hormones, particularly testosterone and cortisol, may seriously influence financial decision making in traders. They showed that cortisol, a hormone that modulates the response to physical or psychological stress, predicts instability in financial markets. Specifically, they recorded level of cortisol and testosterone in saliva samples of 142 participants and found that individual and aggregate levels of endogenous cortisol predict subsequent risk-taking and price instability. They further administered cortisol or testosterone to young males before playing an asset trading game and found that both cortisol and testosterone shifted investment towards riskier assets. Based on their conclusion, cortisol should affect risk preferences directly, but testosterone influences risk taking by increasing optimism about future price. Carney *et al.* (2013) reported a correlation between power posing and levels of hormones such as testosterone and cortisol, as well as financial risk taking, and self-reported power feeling in a sample of 42 participants [24]. And finally**,** Apicalla *et al.* (2015) did a review study on the association of testosterone to economic risk taking. As the outcome of the study, they concluded that testosterone acts to modulate risky behaviors in ways that appear to be adaptive [25].

Ronay *et al.* (2016) replicated the study by Carney et al.'s (2010) which found that configuring participants into high power versus low-power physical postures caused increases in objective feelings of power, testosterone, and risk-taking as well as decreases in cortisol. They attempted to extend this pattern of findings by testing the mediating role of testosterone and overconfidence in the relationship between power poses and risk-taking. They hypothesized that increases in testosterone in response to high-power poses would lead to increases in overconfidence, and that this indirect pathway would mediate the effect of power posing on risk-taking. However, they could not replicate the findings of the original study and subsequently found no evidence for their hypotheses and reported that overconfidence was unaffected by power posing and unrelated to testosterone, cortisol, and risk-taking [26]. However, this kind of extension and replicating of existing findings is an interesting way to conduct and develop new hypotheses. Similarly, Smith and Apicella (2016) tried to assess the effect of power poses on testosterone and risk-taking following competition. In a sample of 247 male participants, natural winners and losers of a physical competition were assigned by the chance to hold a low, neutral or high-power postural display which demonstrated no notable effect of pose type on testosterone, cortisol, risk or feelings of power. Winners holding to a high-power showed a slight increase in testosterone compared to winners who held neutral or low-power poses. Among the losers, they found little evidences that high-power poses would lead to high testosterone relative to those holding neutral or low-powered poses [27].

Risky decision making is a common part of adolescence, perhaps related to sensation seeking rise, ongoing maturation of reward and dopamine systems in the brain, modulated by sex hormones. Understanding neurobiological mechanisms that change adolescent sex differences in risky decision making is a key to individual diversity that lead to different behaviors that affect health outcomes. Alarcón *et al.* (2017) examined sex differences in the neural substrates of reward sensitivity during a risky decision-making task and predicted that boys would show heightened brain activation in reward-relevant regions compared with girls, particularly the nucleus accumbens (a brain region in the basal forebrain rostral to the preoptic area of the hypothalamus), during reward receipt. They considered that testosterone and estradiol levels would mediate this sex difference and hypothesized that boys would show more risky choices on the task. The results showed when boys showed increased nucleus accumbens blood oxygen level-dependent reaction relative to girls, this effect was not mediated by sex hormones. Boys made more risky decisions during the task, as it was hypothesized and also self-reported more desire to perform well and earn money on the task, while girls self-reported more state anxiety prior to the scan session. The effect of sex on nucleus accumbens activity during reward was partially mediated by money earning motivations [28]. Focusing on adolescents, Cardoos *et al.* (2017) dealt with adolescence risk taking to examine pubertal hormones levels in girls in order to find a correlation with their appetite for greater financial risks to gain social status. They provided the hypothesis that testosterone level in pubertal maturation ages is associated with intention to sacrifice money to achieve social admiration. 63 girls in the age of 10–14 took part in laboratory measures and completed at-home saliva sample. The Pubertal Development Scale (PDS) and basal hormone levels (testosterone, estradiol, DHEA) measured pubertal maturation. They took advantage of a developed version of Auction Task in which participants could take financial risks to gain social status. Both PDS and testosterone were related to overall levels of financial risk taking during the Auction Task and in hierarchical models, the predictors of the overbidding slope over the course of the task. Their results proved the role of testosterone and pubertal maturation in girls' motivations to enter in costly decision making for gaining social status achievement [29]. Nadler *et al.* (2017) did a study to check testosterone casual effect on trading and prices. They heightened testosterone level in male traders to test its effect both on their trading behavior in experimental asset markets and the size and duration of asset price bubbles. They found that increased testosterone in men causes larger and longer-lasting bubbles by causing high bids and the slow incorporation of the asset's fundamental value [30]. Danese *et al.* (2017) used two novel testes to relate economic behaviors to hormone levels. They investigated the relationship between testosterone and cortisol on one side and attitudes toward risk and ambiguity on the other. They asked 78 undergraduate male students to complete several tasks and give two saliva samples. In one task "Reveal the Bag," they expressed their beliefs on an ambiguous situation in an incentivized framework. In another task "Ellsberg Bags," participants talked about their reservation prices for a risky bet and an ambiguous bet through an incentive-compatible mechanism (For further information, see Danese *et al.* 2017). Ambiguity premium was measured by the difference between prices which clarified that salivary level of testosterone and cortisol jointly affected the ambiguity premium. They reported lower levels of two hormones lead to the highest levels of ambiguity aversion. They also claimed that the expressed beliefs by a subset of participants in the "Reveal the Bag" task rationalized their choices in the "Ellsberg Bags" task [31].

Digit ratio (2D:4D) (which is the ratio between the length of the second and fourth digit and is a measure for prenatal testosterone exposure, the higher the (2D:4D), the lesser prenatal testosterone exposure**)** has always been an interesting proxy for testosterone in neuroeconomic. In 2017 many studies focused on this ratio. Considering gender imbalance on financial traders, Xie *et al.* (2017) investigated gender differences in financial risk taking under pressure. They used an approach from behavior economics to assess risky monetary choices by male and female participants in presence and absence of time pressure. They also used digit ratio (2D:4D) and face width-to-height ratio (fWHR) as markers of pre-natal exposure to testosterone. Relying on a structural model, they estimated the risk attitudes and probability perceptions with high likelihood estimation under both expected utility and rank-dependent utility models. They reported less risk aversion for men and increased gender gap in risk attitudes under moderate time pressure. The study showed that women with lower 2D:4D ratios and higher fWHR are less risk averse in rank-dependent utility estimates, and men with lower 2D:4D ratios are less risk averse in expected utility estimations, but more risk averse using rank-dependent utility estimates. Further, male participants with greater prenatal testosterone exposure showed more optimism and overestimate small probabilities of success [32]. Werner Bönte1 *et al.* (2017) examined the relationship between 2D:4D and competitiveness in individuals, employing two measures for competitiveness, behavioral measures from economic experiments and psychometric self-reported measures. They designed two independent surveys and economic experiments studies with a data set of 461 shopping mall visitors (The first study) and 617 university students (The second study). Both studies provided no significant evidences or a relation between behavior in the economic experiment and digit ratios of both hands. But, a negative and significant correlation between psychometric self-reported measures of competitiveness and digit ratios (R2D:4D) of right hand was observed in both studies which especially was strong for younger participants [33].

Besides the biological function, testosterone and cortisol have a significant effect on financial decision-making. Herbert (2018) prepared a review on experimental and laboratory research related to the effect of testosterone and cortisol in risky financial decisions. The study provides a recent report on the effect of testosterone and cortisol on risk-appetite, reward valuation, information processing and estimation of the costs or benefits of probable success or failure. The study also considered mapping these actions on neural system underlying risk preference and decision-making, with reference to areas of the brain engaged in either cognitive or emotional functions [34]. Nofsinger *et al.* (2018) emphasized the importance of the endocrine system on financial decision-making. They studied the relation between testosterone, cortisol, and financial decisions in a group of unskilled investors. They reported excess risk-taking is positively correlation with testosterone level and negatively with cortisol level. They also found reliable evidence for a dual-hormone hypothesis in a financial context, specifically the testosterone-to-cortisol ratio which is significantly related to loss of aversion, whereas individuals with a higher ratio are 3.4 times more likely to sell losing stocks. Furthermore, they reported that there is a positive feedback loop between financial success, testosterone, and cortisol, where higher post-trial testosterone and cortisol is significantly related to financial success by a factor of 0.53 (SE: 0.14). Finally, they claimed that in competitive environments, testosterone level increases significantly, leading to greater risk- taking compared with noncompetitive environments [35]. Kurath and Mata (2018) delved into assigning the relation of endogenous testosterone, estradiol, and cortisol levels and constructs relevant to risk-taking (i.e., impulsivity, tendency to risk-taking, novelty seeking and sensation seeking) to find a biological base for different levels of risk taking among individuals. The results showed little correlations between risk-taking constructs and testosterone as well as estradiol, but not cortisol. As the results show, testosterone has more action on risk preference [36].

Branas-Garza *et al.* (2018) investigated the links between the digit ratio (2D:4D and two scales of risk taking in individuals, risk preferences over lotteries with real monetary motivations and self-reported risk attitude. They made a dataset from five experimental studies with more than 800 subjects and found a significant relation between digit ratios of both right and left hands and risk preference. They reported that lower digit ratios led participants to riskier lotteries and digit ratio, however, is correlated with self-reported risk attitude [37]. Dalton and Ghosal (2018) focused on the question that if the fetal testosterone exposure forestalls the confidence and over-confidence in own absolute ability in adulthood. They extracted incentive-compatible measures of confidence and over-confidence in the lab and linked them to the right hand 2D:4D ratio. They reported the low 2D:4D (higher testosterone exposure) leads men to set less unrealistically high expectations about their own performance which helps them to achieve higher monetary rewards a vice versa for men with higher ratio [38]. Millet and Buehler (2018) explained incoherence in the literature on the relation between 2D:4D and risk taking, aggression and dominance related consequences and investigated in their empirical study how attitudes in low 2D:4D men may change as a function of the status relevance of the context. Their evidences approved the idea that status relevance of the specific situation at hand affects the attitude towards performance-enhancing means for men with low 2D:4D, but not for high 2D:4D men. They even claimed that any behavior that is functional to gain status in a specific context may be related to 2D:4D [39].

In recent years, neuroeconomic studies have been more concentrated on interactive effect of hormones on human behavior instead of focusing on a single hormone. Wu *et al.* (2019) studied testosterone effects on social distance-dependent generosity in an economic discounting task where people could choose between generosity and selfishness in a double-blind procedure, testosterone gel or placebo was administered to men, randomized design and measured how willing the participants were to share rewards with close and distant others. During two studies with 174 participants, social discounting firmly grew due to testosterone administration; people started to show more selfishness especially to distant others (vs. close others). They concluded that testosterone level has a negative relation with human generosity in economic decision-making. Moreover, they also suggested that testosterone affects valuation and perception of social distance independently [40]. Alacreu-Crespo *et al.* (2019) ran a study to test the role of testosterone changes moderated by cortisol changes after competition in decision-making for both men and women. 94 participants (48 males and 46 females) were asked to complete the Iowa Gambling Task (IGT) after a laboratory competition or a noncompetitive task as the control task. Saliva samples were collected before and after the competition/control task. Considering the uncertainty level, IGT was used for measuring risk-taking decision-making. The results supported sex-differentiated effects of testosterone and cortisol changes on risk-taking action. In both competition and control task groups, men with higher cortisol and testosterone changes after competition demonstrated higher risk-taking decision-making (higher IG Risk). On the other hand, women with high cortisol and testosterone from the competitive task showed conservative decision-making. Therefore, these results show sex-differentiated decision-making profiles, which can explain how different sexes react after a competitive social context experiment [41]. Tycho Dekkers (2019**)** discussed that according to the dual-hormone hypothesis, cortisol moderates the relation of testosterone and status behaviors, just in the case of low cortisol level. The research performed a meta-analysis (including 30 papers with 33 studies, 49 effect sizes, *n* =8538) on the interplay of testosterone and cortisol on status-relevant behaviors similar to risk preference, domination, psychopathy and aggressiveness. The dual-hormone hypothesis was supported just by marginal evidence effects, emphasized by follow-up meta-analyses on simple slopes on cortisol low and high level, the interaction effect size of testosterone and cortisol on status-relevant behaviors was significant and small. For direct status measurements the effect size was the largest, but not remarkably different from other measurements. Likely, effect sizes for men were more significant compared with women. The dual-hormone hypothesis claims that testosterone is particularly related to status-relevant behavior just in the case of low and not high cortisol level [42].

Cortisol and financial relevant studies

Power expression in human is through open, expansive postures, and powerlessness is presented through closed, contractive postures. Carney *et al.* (2010) put forth the hypothesis that mentioned postures can lead to power. They assigned 26 females and 16 males to high and low power poses randomly and informed them it was a study on electrocardiography. Individuals were posed to high and low power poses each for one minute. (For more information on the power poses, see Carney et al., 2010). Risk taking and power feeling were measured with gambling task and self-reports, respectively.17 minutes after power posing, saliva samples were collected for cortisol and testosterone levels. The results showed that posing in high-power nonverbal displays would cause neuroendocrine and behavioral changes for both male and female participants. They reported that High-power poses caused elevations in testosterone, decreases in cortisol, and increased feelings of power and tolerance for risk; low-power poses led to the opposite pattern [43]. Coates *et al.* (2010) ran a survey research on steroid hormones and their cognitive effects, and examined potential links to trader performance in the financial markets. Preliminary findings suggested that cortisol codes for risk and testosterone for reward. An important finding of the research was the different cognitive effects of acute versus chronic exposure to hormones. Based on the research, acute rise in steroids led to performance optimization on a range of tasks; but chronically elevated steroids might help illogical risk-reward choices. They suggested that the irrational exuberance and pessimism observed during market bubbles and crashes could be mediated by steroid hormones [44].

Sensation seeking (SS) is defined "as a trait defined by the seeking of varied, novel, complex and intense sensations and experiences, and the willingness to take physical, social, legal and financial risks for the sake of such experiences" (Zuckerman, 1994, P. 27) [45]. In an effort related to the effect of serotonin and cortisol on sensation seeking, Shabani *et al.* (2011) examined the possible relationship of serum serotonin and salivary cortisol with the sensation seeking trait. Serum serotonin and salivary cortisol concentrations were measured in 57 male volunteers and SS was assessed with Zuckerman's Sensation Seeking Scale. Pearson's correlation coefficient determined that high serum serotonin levels did not correlate significantly with low SS scores. However, the significant negative correlation between SS scores and salivary cortisol levels suggested the correlation between high SS scores and low concentrations of salivary cortisol which is compatible with the optimal level of Catecholamine system activity (CSA), component of SS theory - The model of optimal level of CSA suggests that in an unstimulated state and low basal level of CSA, dopamine and norepinephrine are low in HSSers and are much below their optimal levels of CSA. This produces a state of boredom, which in turn, compels the individual to seek novel and risky experiences indicating that high sensation seekers look after excitement and novelty to compensate for the shortage of CSA achieving optimal arousal [46]. In the mechanisms of behavioral inhibition, Tops *et al.* (2011) studied the association between cortisol and post-error slowing- a measure that depends upon brain areas involved in behavioral inhibition- and tried to know whether this association remains after controlling for positive associations with behavioral inhibition scores and error-related negativity (ERN) domains that cortisol and post-error slowing may share. Eighteen healthy right-handed female participants, between 18 and 27 performed a flanker task. In line with the hypothesis that cortisol may involve in behavior inhibition, this hormone was reported independently positively associated with post-error slowing and the ERN. The results also indicated that cortisol mediates the relation between ERN and more post-error slowing, which creates a direct association between ERN and less post-error slowing [47].

Zalewski *et al.* (2012) examined the association of low income and poverty with cortisol levels, and explored probable pathways from low income to disruptions in cortisol through cumulative family risk and parenting. In a sample of 306 mothers and their preschool children included different level of financial wealth they found that lower income is related to lower morning cortisol levels, and cumulative risk predicts a flatter diurnal decline, with a remarkable indirect effect through maternal negativity, proposing that parenting practices might mediate an allostatic effect on stress physiology [48]. Decision making has been shown to be diminished by stress, then any factor which affects stress has a potential effect on decision making. Pabst *et al.* (2013) hypothesized that the quick stress induced increase in norepinephrine and the delayed increase in cortisol could exert opposing effects on decision making under risk. Participants were 40 male students aged 18-34 divided into one control group and three different stress groups which underwent the Trier Social Stress Test (TSST) to induce acute stress and performed the Game of Dice Task (GDT) to assess decision-making behavior at different time points in relation to the stressor, which lasted approximately 18 min. 5 min after the beginning of stressor, the first group accomplish the GDT; the second and third group took the GDT either 18 or 28 min after TSST onset. In the control group, decision-making performance was measured after a resting time. The results showed a fast activation of the sympathetic nervous system and a slightly slower response of the hypothalamic pituitary adrenal axis. They also reported that a moderate increase in catecholamines (sympatric hormones) improved decision-making performance, and cortisol concentrations increase was likely to negatively affect decision making presumably via rapid nongenomic mechanisms [49]. Daughters *et al.* (2013) researched the effect of psychological stress, gender and cortisol on stress relates to risk behavior in adolescents. 132 adolescents including 59 boys and 73 girls completed a laboratory risk task before and just after a computerized psychological stress task. Salivary samples were collected from pre-stress to 60 min following initial stress exposure for cortisol measurement. They reported that stress increases risk taking in boys and decreases it in girls. Additionally, both a smaller total cortisol output and peak cortisol response to stress were reported associated with greater stress-induced risk taking in boys and not associated in girls. They concluded that a blunted cortisol response to stress led to an increase in risk taking in the context of psychological stress in boys [50]. Vaghri *et al.* (2013) examined the correlation of children's hair cortisol and socioeconomic status of the family, as measured by parental education and income. Low socioeconomic status of the family is considered as long-term environmental stressful factors, and the hair cortisol is an indicator for the cumulative stress exposure across an extended period of time. They collected data from hair cortisol, family income, and parental education from a sample of 339 children in Vancouver and reported a significant correlation between hair cortisol and parent's education, but no noticeable relation was found between parental income and hair cortisol [51].

Pathological gambling is a behavioral addiction characterized by a chronic failure to resist the urge to gamble which has a lot in common with drug addiction. Affecting the mesolimbic reward pathway, Glucocorticoid hormones, like cortisol, are thought to have an important role in the vulnerability to addictive behaviors. Based on their prior report of an imbalanced sensitivity to monetary in compare with non-monetary motives in the ventral striatum of pathological gamblers (PGs), Li *et al.* (2014) tried to explore whether this imbalance was mediated by individual differences in endogenous cortisol levels. Using functional magnetic resonance imaging, they assessed the effect of cortisol levels on the neural reaction to monetary versus non-monetary cues, while PGs and healthy controls (20 males in each group) were participated in an incentive delay task manipulating both monetary and erotic rewards. The study confirmed the positive correlation between cortisol levels and ventral striatal- a part of brain related to rewarding system- reaction to monetary versus erotic cues in PGs, but not in healthy controls which confirmed that the ventral striatum is a key region where cortisol modulates incentive motivation for gambling versus non-gambling related stimuli in PGs [52]. Weller *et al.* (2014) made an effort to find whether the diurnal cortisol rhythm as neuroendocrine markers of stress is related to higher-order cognitive processes such as decision-making. In a sample of 69 healthy older adults aged 55–85 including 40 females, they found that decrease of diurnal cortisol affects performance on the Cups Task, a risky decision-making task that independently tests risk taking to achieve gains and risk taking to avoid losses. For potential gains, they reported that higher risk-taking is related to lower diurnal cortisol decrease, irrespective of age or sex. In the case of risks to avoid potential losses, lower diurnal fall selectively was reported associated with suboptimal decision-making just for males. The results also indicated that compared with males with more normal diurnal fall, individuals who presented lower diurnal fall made more risky choices and demonstrated lower sensitivity to the expected value of the risky choice.Personal and environmental factors affect hormonal changes and savage behaviors which are characteristics of adolescent [53]. Finy *et al.* (2014) assessed the interactions between psychosocial stress and the traits of negative emotionality and constraint on impulsive and risk-taking behaviors as well as salivary cortisol reactivity in 88 adolescents. In terms of behavioral outcomes, their research revealed that negative emotionality and constraint were protective of impulsivity and risk taking, respectively, for adolescents in the no-stress condition; personality was not related to either behavior in the stress condition. Low-constraint participants in the stress condition were reported to be engaged in less risk taking than low-constraint adolescents in the no-stress condition, whereas there was no effect of stress group for high-constraint adolescents. In terms of cortisol reactivity, the analyses revealed that low-constraint adolescents in the stress condition showed greater cortisol reactivity in compare with high-constraint adolescents, which suggests that low-constraint adolescents mobilize greater resources in stressful situations relative to not stressful ones. The results demonstrated that two facets of disinhibition and cortisol reactivity were differentially affected by psychosocial stress and personality (and their interactions) in adolescents [54].

Cueva *et al.* (2015) tried to link financial market disabilities to cortisol which modulates the response to physical or psychological stress. Assessing salivary cortisol and testosterone of 142 individuals in an experimental asset market, they found that cortisol level might estimate individual and aggregate levels of endogenous cortisol, following risk-taking and instability in prices. Administering either cortisol or testosterone to young males before engaging in asset trading game, they claimed that cortisol and testosterone cause investing in riskier assets. The study suggested that risk preference is directly related to cortisol but testosterone acts the same by increasing optimism about future price changes and both the hormones can cause market destabilization by changing risk taking behavior [55]. Mehta *et al.* (2015) explored the testosterone's role in risk-taking depends on cortisol. They examined this effect in one study with 115 males and females with self and informant reports of risk-taking, and in another study with 165 males with the Balloon Analog Risk Task which is a behavioral measure of risk-taking. Both studies showed a positive association between basal testosterone and risk-taking among people with low basal cortisol but not in participants with high basal cortisol. They concluded that testosterone and cortisol jointly regulate risk-taking [56].

Stress can modulate decision-making processes, time passing after stress exposure seems to be an important factor that indicates this effect direction. Bendahan *et al.* (2016) evaluated economic risk preferences on the gain domain similar to risk aversion at three time points after psychosocial stress induction (immediately after, and 20 and 45 min from onset). Using lottery games, they assessed decisions in individual and social levels and found that risk aversion demonstrates a time-dependent change across the first post-stress hour from less risk aversion just after stress to more risk adverse behavior at the last time point. The study showed while risk leads to antisocial results to a third party, stressed participants represent less attention to this person in their decisions; and cortisol level clarifies the individual behaviors in the risk, but not the antisocial, game [57]. Linking chronic stress and decision-making in a sample of 205 young adults, Ceccato *et al.* (2016) measured risk taking in the gain domain and self-reported chronic stress respectively through binary choices between financially incentivized lotteries and Trier Inventory for the Assessment of Chronic Stress. Quantifying cortisol accumulation as a stress hormone, hair samples of volunteers were collected. The results showed a positive association of self-reported chronic stress and risk taking especially for women and no correlation between hair cortisol and behavior. The study obviously identified a gender difference in risk taking and self-reports, suggesting women mostly take less risk and report a little higher stress levels than men. All together they concluded that comprehend chronic stress can affect behavior in risky positions [58]. Samuel *et al.* (2016), in a multivariate study, hypothesized that lower socioeconomic status -as a proxy for socioeconomic vulnerability and education- and African American race are associated with lower waking cortisol and slower afternoon decline. During 24 hours, they collected six salivary samples of 566 individuals aged 56-78 for cortisol measuring and compared results of African Americans with all others. The study claimed that adjusted for age and sex, intermediate, but not low, education is associated with approximately 17% lower average waking cortisol and 1% slower decline, compared with high education. But there is no association between socioeconomic vulnerability and waking cortisol or linear decline. In terms of African American ethnicity, the results showed that socioeconomic vulnerability is related to a 3% faster decline, but no association between education and cortisol [59].

Acute stress may increase risky decision-making in men, while there is no such effect in women. Kluen (2017) tried to explain the role of cortisol and noradrenergic changes in risky decision-making in men and women. In a fully-crossed, placebo-controlled, double-blind design, 51 males and 52females took orally either a placebo, hydrocortisone, yohimbine, an alpha-2-adrenoceptor-antagonist which causes increased noradrenergic stimulation, or both drugs before completing the balloon analogue risk task, to measure risk-taking. Based on the results, cortisol caused considerable increase in risk-taking in men, but it was showed that it had no effect on risk-taking behavior in women. In term of yohimbine, it seemed not to have any such effect or to modulate the gender-specific effect of cortisol. The research supported that cortisol enhances risk-taking behavior in men but not in women who may drive gender differences in risky decision-making under stress [60]. Danese *et al.* (2017) investigated the relevance between testosterone and cortisol on one hand and attitudes toward risk and ambiguity on the other. As the sample, they asked 78 undergraduate male students to provide two saliva samples and do “Reveal the Bag,” and “Ellsberg Bags,” to elicit their beliefs on an ambiguous situation in an incentivized framework and reservation prices for a risky bet and an ambiguous bet, ambiguity premium was calculated by the difference of two prices. They found that salivary testosterone and cortisol levels together anticipate the ambiguity premium, and individuals with lower levels of the two hormones demonstrate the highest ambiguity aversion [61]. *Barel et al.* (2017) made an effort to develop the focus of the dual-hormone hypothesis on testosterone and cortisol connection in risk-taking to estrogen and progesterone as other sex hormones. They tested 107 participants, 40 women and 37 men for circulating sex hormones and collected self-reports on risk-taking. They reported that the ratios of sex hormone–cortisol modulate risk-taking in men and women differentially. In men, high ratios are related to risk-taking, while the opposite pattern is true for women [62].

Human has the attitude to overweigh loses in comparison with the same amount of gain and loss aversion as a common behavior in financial decision making. Margittai (2018) investigated the effect of cortisol and noradrenaline on loss aversion during financial decision making, orally administered either with the α2-adrenergic antagonist yohimbine (increasing noradrenergic stimulation), hydrocortisone, both substances, and a placebo to healthy young men, in a double-blind, placebo-controlled between-subject design. They tested the effect on a financial decision-making task measuring loss aversion and risk attitude. The results claimed that when combined both drugs, compared with either drug alone, have a negative effect on loss aversion in the absence of an effect on risk attitude or choice consistency and proposed that simultaneous glucocorticoid and noradrenergic activity may result in an alignment of reward- with loss-sensitivity, and thus decline loss aversion [63]. Kurath and Mata (2018) conducted a review and independent meta-analyses to assess the link between endogenous testosterone, estradiol, and cortisol levels and risk-taking related constructs like risk-taking tendency, impulsivity, sensation and novelty seeking. They reported small correlations between risk-taking constructs and testosterone as well as estradiol, but not cortisol. Most importantly, the study suggested biological foundation for individual differences in risk taking. It is also a worthy recent review on the subject of current paper [64].

Alacreu-Crespo (2019) conducted a study to test the role of testosterone changes in decision-making moderated by cortisol. They asked 48 males and 46 females to complete the Iowa Gambling Task to assess risk-taking decision-making based on the uncertainty level. The results showed that men with higher testosterone and cortisol changes after competition from both task groups demonstrated higher risk-taking decision-making and women from the competitive task with higher testosterone and cortisol represent conservative decision-making. Based on the findings, they confirmed sex-differentiated decision-making profiles, which can help to know how men and women behave after experiencing a competitive social context [65]. Stress plays a remarkable role in decision-making especially under risky situation. Using binary lotteries from the one-urn Ellsberg paradigm, Du and Levy (2019) tested the effect of acute stress on decision-making. Administering with nine subjects, they concluded that in relation to the control condition, stress led to more risk averse when expected winnings were low, and more risk was sought when expected winnings were high, stressed subjects also had slower reaction times when making decisions. The study reported that acute stress increases cognitive load, but ultimately, eases decision-making under risk and ambiguity. One of the most basic pillars of the economics is rationality but it is not clear whether this assumption holds true when decisions are made under stress [66]. Cettolin *et al.* (2019) made two laboratory experiments to exogenously induce physiological stress in participants and test their choices constancy with economic rationality. They induced stress through the

Cold Pressor test and assessed economic rationality by the consistency of participants' choices with the Generalized Axiom of Revealed Preference (GARP). In the first experiment, participants showed *delay* on the decision-making task for 20 min until the cortisol level peaked and a significant difference in cortisol levels between the stressed group and the placebo group was found which, however, did not affect the consistency of choices with GARP. In the second experiment, they studied the *immediate* effect of the stressor on rationality and confirmed that rationality was not impaired by the stressor. They found that compared with the placebo group, participants were more consistent with rationality just after the stressor. They claimed the results were solid empirical evidence for the robustness of the economic rationality assumption under physiological stress [67]. The fight and flight theory and the tend-and-befriend theory suggest two completely different behavioral stress reactions. Different studies have underlined the importance of sex. Zhang *et al.* (2019) designed a study to investigate the relation between stress-related cortisol reactivity on following prosocial decision-making behaviors, and the moderating role of sex and empathic concern in the process. As the sample, sixty-one students including 34 women and 27 men were assigned as the Trier Social Stress Test for Groups or the control condition and completed three economic tasks—the dictator game, the ultimatum game, and the third-party compensation game. The study results showed a significant effect of cortisol reactivity on individuals' third-party compensation behaviors sex. A sex-specific effect of stress-related cortisol change on prosocial behaviors was found in the way men behaved more generously in the dictator game as stress-related cortisol reactivity increased. They also revealed that the level of empathic concern seems to moderate the relationship of change in stress related cortisol and prosocial behaviors, where individuals with a low level of empathic concern reported more generosity and third-party compensation behaviors [68].

Discussion and future perspective

In recent years, different financial behaviours have been emphasized, specially risk related behaviours as vital factors in the risky atmosphere of the markets have been widely the centre of attention from household economics to information technology [69] and macroeconomic related factors such as oil market prices [70]. Researchers from different fields have focused on the biological factors that affect the financial behaviours and even the new field of neuroeconomic specifically focuses on understanding human decision-making by using neuroscience measurement methods [71]. In the first section of the review articles, the studies conducted on the chemical effect of testosterone on financial behaviour and risk-taking were reviewed. As explained earlier, each study changed the level of testosterone in some way, some of which by using pharmaceutical products such as pills and topical gels, some others by using power poses and involving people in fights and competitions, and some others also examining the hormone levels at stages of life, where this hormone changes naturally such as puberty.

Several methods have been used for its measurement, such as measuring the level of the hormone in the blood and saliva. Also, a significant number of studies used the D2: D4 ratio, which is reversely related with level of fetus exposure to testosterone in pre-birth period and its generally more common in men than women. Finally, to measure the effect of the hormone on the level of risk-taking, methods such as questionnaires, self-reports, examining people performance in real or simulated transactions, as well as psychological tests such as Iowa Gambling Task, Ells Bag, Reveal the Bag, have been used.

In this section, we refer to some of the most important results of the studies. As stated, power poses and winning in competitive situations increase testosterone levels and increase risk-taking, and the normal levels of this hormone in the body of people have a positive relationship with level of risk-taking and ambition and change the assessment of risk. Experimental studies of financial markets have shown that increasing the level of this hormone increases the risk of traders, the size and time of retention of price bubbles and, consequently, the instability of markets. Concerning the physiological effects of testosterone on the brain, it has been shown that the activity of some parts of the brain such as OFC and Nucleus Accumbens, which affect risky behaviours, increases under the influence of testosterone, thus increases people risk. Concerning the change of attitudes and behaviours related to risk-taking, testosterone increases people's level of effort to achieve a higher social status and reduce financial generosity.

Some studies have focused on the mediating role of cortisol in the relationship between testosterone levels and risk-taking, which will be examined in studies related to cortisol. During the ten-year period of these studies, a number of comprehensive review and meta-analysis articles have been conducted that provide a comprehensive view of previous studies. In the studies on the relationship between cortisol and financial behaviours, different methods such as drug, Power Poses, Cup Task, Cold Pres Test, and Trier Social Stress Test (TSST) were used to change the level of this hormone. To measure the level of cortisol in the mentioned studies, the level of hormone in the saliva sample was mainly used, but in some cases, the level of cortisol in people hair was also considered.

Some of the methods used to measure behavioural changes including financial and risk preferences are Generalized Axiom of Reveal Preference (GARP) used to measure people's credit logic, Gambling Task, Game of Dice Task (GDT), Iowa Gambling Task, and Lottery. Game, Ellsberg Task, Balloon Analog Risk Task, Reveal the Bag, and Sensation Seeking to determine the level of tendency of people to take risks. In general, increasing cortisol reduces people risk-taking, so any factor that increases cortisol levels indirectly reduces people's risk-taking and changes the market stability. These factors include exposure to Power Poses and exposure to competitive and stress situations. In this regard, stress in both cross-sectional and long-term states has significant effects on increasing cortisol levels and reducing risk. This effect is more in males than females. Gender is a factor that changes the effect of cortisol on people behaviour.

Many studies have investigated the combined effects of testosterone and cortisol on risk-taking and it has been found that cortisol plays an important mediating role in the relationship between testosterone and risk-taking. Another important point is that cross-sectional and long-term exposure to cortisol yields different results, so that cross-sectional increase of steroid hormones such as cortisol improves function, while long-term high levels of these hormones cause irrational behaviours in risk-taking area. Concerning the effect of cortisol on the brain, we can also refer to a study that links the level of this hormone with ventral-striatal, a part of the brain that is related to the reward system.

Research studies conducted on the effects of hormones on changing the financial behavior have had much strength and have clarified this issue to a large extent, but since this is a relatively new subject, many other studies can be also done in this regard. Here, some recommendations for future studies are presented. In most studies, only one dose was used to manipulate hormone levels to change hormone levels, while long-term changes in hormone levels, for example, 10 to 14 days or more, can be used to assess the effect of long-term hormone manipulation on financial behavior. It is crucial to investigate whether body activates regulatory mechanisms after long-term exposure to hormones. Hence, by keeping the sample constant and the hormone level constant at a certain level, it is possible to neutralize the effect of other time-dependent variables to some extent.

Similarly, people who have congenitally abnormal low or high levels of the hormone due to long exposure can be investigated, and the results of their risk-taking tests can be compared with the results of people with normal hormone levels. Physical and psychological changes cause a change in hormone levels and a change in people's attitudes toward risk-taking and other financial behaviors, so it is possible to examine the effect of variables such as age, puberty, employment status, marital status, and having diseases such as depression and others in the relationship between hormones and financial behavior. People living in different geographical areas over the generations show different patterns in behavior due to the impact of the environment and weather conditions, so investigating the effect of race and geographical area on financial behavior can be a subject of future studies. Since most of the hormonal changes in the body occur in early adolescence, when people are studying in university, the field of study and consequently job of people may be effective in assessing their risk. Different markets have different characteristics, for example, the risk in the foreign exchange market and the precious metals and securities are different from that of each other markets, so the activists of these markets are exposed to different levels of risk, which can affect their assessment of risk and provide the venues for further studies.

Another aspect that researchers can focus on for analyzing data of the experimental studies is the utilization of advanced statistical models same as artificial neural networks (ANN). ANNs refer to a class of models generated by biological neural systems. The concept underlying ANNs is on the basis of computing systems that are capable of learning by experience *via* recognizing patterns available in a data set. After identifying necessary inputs (factors), a neural network can be simply trained to form a non-linear model of the underlying system. The model is then generalized to new cases that are not part of the training data [72]. Due to high accuracy, using the mentioned models can be highly beneficial in data analysis, prediction of future trends and, finding hidden patterns in the data driven from experimental studies.

Conclusion

Contrary to the assumptions of classical economics, which were based on rational investment behaviors, modern economics seeks to examine irrational investment behaviors and the factors that influence these behaviors. Controlling part of human behavior is influenced by the chemical effects of hormones, while steroid hormones such as testosterone and cortisol have a significant effect on the severity of financial behaviors such as risk-taking. In the decade leading up to 2019, several studies were conducted in this area, which reviewing some of the most important of these studies was the subject of current research. As mentioned, these hormones have a great impact on the capital market by affecting brain chemistry and, consequently, financial behavior, thus creating an important field of research. Gaining knowledge on ways and levels of the chemical and psychological effects of hormones on financial behaviors can improve the performance of market activists and ultimately the growth of the capital market.

Acknowledgements

Authors acknowledge for helpful comments of the peer reviewers.

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How to cite this article: Asghar Beytollahi. Chemistry of financial behaviors: a mini review of hormones effect on financial behaviors (2010-2019). *Eurasian Chemical Communications*, 2020, 2(8), 916-937. **Link:** http://www.echemcom.com/article_110292.html