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Chemistry of the Behaviors, Assessing the Effect of Testosterone, Cortisol, Progesterone and Estradiol on Financial Risk Taking using Machine Learning Regression Methods

Asghar Beytollahi*, Fariba Marashy

Faculty of Accounting, Kerman Azad University, Kerman, Iran

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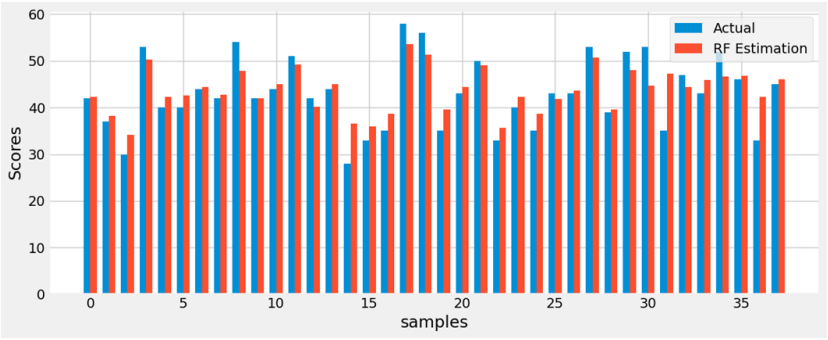
ABSTRACT

Human behavior is the consequence of the interactions between physiological and biological factors. On the other hand, biochemical hormones are crucial indicators that widely impress the human life. Financial behaviors are the same as risk attitude which affect the economic and social quality of human life, and are also driven by the hormones which are biochemicals that circulate with the blood and govern the targeted parts of the body, mostly the brain. Cortisol, Testosterone, Progesterone, and Estradiol are some of the hormones that shape the human life with the extensive impact they have on emotional conditions and obviously change the individual tendency to financial risk taking. The present study is an experimental work which assesses the effect of the four mentioned hormones levels on the financial risk taking score. The levels of these hormones are measured in the blood samples provided by 38 participants. The participants further filled a standard and reliable questionnaire which indicates the level of financial risk taking. Several regression methods of machine learning are applied to the produced database and it is concluded that the value of financial risk taking could be modeled by Testosterone, Cortisol, Progesterone, and Estradiol hormone concentrations. The statistical analysis is also performed and it is demonstrated that testosterone has a positive effect on the financial risk taking whilst the other three hormone levels are negatively associated with the financial risk taking.

GRAPHICALABSTRACT



* Corresponding author: Asghar Beytollahi
E-mail: hamibeytollahi89@gmail.com

Introduction

Experimental observations beside the scientific progresses during the last decades have conducted new connections between different fields of studies. Topics which previously were considered unrelated, now are joining to each other and making new routes in science, for instance, neuroeconomics which attempts to link different factors of neuroscience and psychology to the economic behaviors [1] and obviously consider the physiological, biological, and biochemical factors which are the main tools of neuroueconomics.

Financial behaviors including the risk taking are importantly effective on the social and economic situation of the people life. Risk taking is commonly defined as the tendency to take or averse the risk by individuals, more specifically risk taking is any deliberately or unintentionally controlled action with an understood doubt about its consequences, and/or about its potential advantages or expenses for the physical, economic, or psycho-social well-being of oneself or others [2]. Based on a well-known equation in economics, more the risk more the return someone will gain, it is famous as the risk-return equation. A good example to provide is the return of the government bonds which is less than company bonds, cause the prior bear lesser risk in compare with the later ones. Then, higher risk taking may lead to higher gain and the risk attitude is driven from various factors same as age, sex, income, physiology and psychology. All the human behaviors including financial ones are the results of mental situations provided in the brain and the central nervous system which the chemical hormones have a great impact on both of them. Hormones are biochemical substances secreted into blood stream by the glands [3] and widely affect the target parts of the body. Brain is one of the organs which not only produce many hormones, but also have many receptors for a wide range of them. Therefore, the hormones through the effect they have on the brain are considered as the most crucial keys which explain the cognitive and behavioral situations of the humans [4]. Based on the previous studies, testosterone, cortisol, progesterone, and estradiol have always been considered amongst the hormones which drastically influence the functions of the brain and seriously connected with the behaviors [5,6].

Testosterone is a gonadal hormone produced in both sexes with receptors all over the body. This hormone has a crucial role in sexual functions and body masculinization especially in men. Antisocial and aggressive behaviors are vastly associated with testosterone. The connection among changing mood, aggression, sexuality, and financial treatments to the testosterone level have been reported in many different studies as well as mutual association with aggressive behaviors, gonadal hormones the same as testosterone are connected to competition, spatial tasks, memory, sensation seeking scales, and risk attitude [7]. Cortisol, as the main glucocorticoid hormone, is secreted and adjusted by the hypothalamic-pituitary-adrenal (HPA) axis which plays a pivotal role to sustain normal physiological homeostasis, and it regulates several operations, including metabolism, cardiovascular biology, immune function/inflammatory reactions, and cognitive function [8]. “Cortisol has been always used in human psychobiological researches as a biological index of stress, anxiety and depression” [8], conditions which highly affect the behaviors, attitudes, and life quality of humans.

Progesterone is a steroid hormone produced in the adrenals, ovaries and Leydig's cells. Although it is commonly assumed as a female hormone, it is also produced in males. Progesterone is vital for normal female reproductive function also in males; progesterone can affect erectile function and sleep patterns. This hormone has been proved to have roles in brain which led to the release of neurochemical signals essential to sexual behavior [9]. Estradiol (E2), is an estrogen steroid hormone, the main sex hormone of women engaged in the regulation of the estrous and menstrual female reproductive

cycles [10]. However, estradiol, the predominant form of estrogen, also plays a critical role in male sexual function. Estradiol in men is essential for modulating libido, erectile function, and spermatogenesis [11]. Progesterone and estradiol are also proved to have effects on the risk attitude in both men and women [12].

Based on the previous discussed paragraphs and according to various recent studies, it is obvious that the hormones, especially the mentioned ones seriously affect the risk attitude and risk taking in humans. Assessing the association between the hormones and financial behaviors would improve our knowledge on the relevance of biochemical elements and individual behaviors.

It would explain the market instabilities, individual's financial irrationalities and the other facts of the financial markets. Many studies have been done on the relation between the same hormones and different financial behaviors. Here, some of the most relevant papers of the few past years are reviewed.

Testosterone and Cortisol

In a study, Coates and Herbert (2008) discussed about the scarce of knowing about the role of the endocrine system in financial risk taking (at the time of the doing their research which was the very beginning of such studies) [13]. They gathered saliva samples from the participants- which all were London male traders- to measure the level of testosterone and cortisol. To assess the risk preferences, they asked individuals to record their profit and loss on the computerized risk-management system. Their results demonstrated that the testosterone level of an individual would estimate his day`s profitability. The results also showed that a trader's cortisol increases with both the variation of trading results and the volatility of the market. They claimed that higher testosterone levels may lead to the economic return whilst cortisol level grows by increasing the risk [13]. With a kind of same purposes, Goudriaan *et al.* (2010) tried to determine if there is any association between testosterone and risky economic decisions [13]. Risk taking and testosterone level were respectively measured through the Iowa Gambling Task (IGT) and saliva samples which were assayed for endogenous testosterone levels using radioimmunoassay.

Based on the results they concluded that participants with higher levels of endogenous testosterone make riskier choices then the low testosterone counterparts and this correlation is bolder in women [14]. Review articles provide comprehensive background of the previous attempts and findings. Therefore, we provide a couple of the literature reviews related to the topic of the current study. Coates *et al.* (2010), in a review article tried to survey the effects of the endocrine system on financial decision-making. More specifically they did a research on steroid hormones and their cognitive influences on trader's performance in the financial markets. Based on the results, they reported that cortisol codes for risk and testosterone for reward. They also determined different cognitive effects of acute versus chronic exposure to hormones and claimed that acutely increased steroids may optimize performance on a range of tasks; but chronically increased steroids may boost irrational risk-reward choices. Finally, they hypothesized that the illogical ebullience and pessimism appeared during market bubbles and crashes may be related to the steroid hormones [15]. Stanton *et al.* (2010) based on the previous studies discussed that testosterone has been considered to have a positive association with risk-taking behavior in social domains [16]. Thus, they assessed the association between endogenous testosterone and economic preferences same as risk preference, ambiguity preference, and loss aversion in a group of individuals. They determined risk preferences via trials in which the participants selected between a certain outcome and a risky gamble. Saliva samples were used to measure the level of testosterone. They reported that in both genders the endogenous testosterone level has a considerable association with individuals' risk and ambiguity preferences, but not loss aversion. More specifically they claimed that people with low or high testosterone tend to be neutral to risk and ambiguity, whilst participants with intermediate levels of testosterone were risk and

ambiguity adverse [16]. Chumbley *et al.* (2014) measured the cortisol level in the hair samples of male participants and asked them to complete some trails for indicating the risk aversion and loose aversion [17]. They demonstrated that people with lower chronic cortisol show more loss aversion, a malefic type of punishment sensitivity steps down long-term payoffs in individuals. In contrast, participants with higher endogenous cortisol weighted losses and gains more equally (lower loss aversion). They concluded that the results emphasize the opinion that in the case of healthy population, long-term exposure to glucocorticoids would adaptively decreases the oversensitivity to potential losses [17]. Risk taking is vital for human activity and it is the core of behavioral sciences such as neuroscience, behavioral economics, and behavioral finance. Kandasamya *et al.* (2014) in an experiment boosted the cortisol level by drug and then assessed the level of hormone in the blood and saliva samples of the participants. They also assessed the level of risk taking by applying a computer task through series of lottery pairs [18]. They found that boosting the cortisol amount would increase the risk aversion in individuals [18]. Apicella *et al.* (2014) discussed that like neuro-economics and endocrinological approaches would provide a possible strong framework to understand decision-making and would help to explain a number of behavioral inconsistencies involving economic risk taking [19]. They dedicated a review to survey advancements that relate the hormone testosterone to economic risk taking and as the study outcome suggested that testosterone modulates risky behaviors in ways that appear to be adaptive [19]. Cueva *et al.* (2015) argued that financial markets would get highly unstable due to the effects of endogenous hormones, in particular testosterone and cortisol which can deeply affect financial decision making in traders and lead to market volatility [20]. Measuring the hormones level in the saliva samples and risk taking through asset trading games, they concluded that cortisol as a modulator of the physical and psychological reaction to stress, would estimate fluctuation in financial markets. They found that individuals and aggregated levels of endogenous cortisol may estimate further risk-taking and price volatility. Administrating cortisol or testosterone to young males before playing the asset trading game, they found that these hormones would lead investments towards riskier assets. Finally, they concluded that cortisol directly influences risk preferences, but testosterone makes affects through inducing high optimism about future price changes [20]. Nofsinger *et al.* (2015) in an attempt tried to investigate the role of testosterone and cortisol levels in finance graduate students on their financial risk taking [21]. The amount of two hormones were measured in the samples of saliva before and after the time that participants took part in financial trails via software which stimulate investment and trading. Based on the results, they claimed that testosterone and cortisol levels have positive connections with financial risk in a competitive atmosphere. In particular, testosterone was reported positively connected to more diversified portfolios. The results also showed that people with higher testosterone demonstrated higher risk asset allocations to gain a higher risk premium; they also were reported to choose more diversified portfolios to decrease unsystematic risk [21]. Mehta *et al.* (2015) in a dual-hormone hypothesis, attempted to explain if testosterone's role in risk-taking is associated with cortisol, or not [22]. To measure testosterone and cortisol, the saliva samples were utilized and the risk taking was determined through Balloon Analog Risk Task (BART) and also self or informant reports. They reported a positive association between basal testosterone and risk-taking among individuals who were low in basal cortisol, but not individuals with high basal cortisol. They also claimed that their results supply new empirical evidences which suggest that testosterone and cortisol jointly regulate risk-taking [22]. Testosterone, a chemical messenger especially influential in male physiology, has been shown to affect economic decision making and is taken as a performance enhancer among some financial professionals. Nadler *et al.* (2017) in their work showed that biological factors affect individual financial decisions that could be reflected in financial

markets [23]. This was the first experimental study which tested how testosterone causally affects trading and prices. They exogenously elevated testosterone in male traders and tested testosterone's effect both on their trading behaviors in experimental asset markets, on the size, and duration of asset price bubbles. Using both aggregated and individual trading data, they claimed that testosterone administration would generate larger and longer-lasting bubbles by causing high bids and the slow incorporation of the asset's fundamental value [23]. Ronay *et al.* (2018) assessed the connections between testosterone, cortisol, and 2D:4D ratio (as a proxy of testosterone exposure before birth), with the overconfidence and risk taking [24]. They measured testosterone and cortisol concentration in hair samples of participants and asked them to do a BART test for determining the level of risk taking and overconfidence. They reported that the results show no proof for a link between hair testosterone concentrations, 2D:4D ratios with risk taking and overconfidence. However, in the case of dual hormone hypothesis, they reported some exciting effects of testosterone and cortisol on risk taking in men. Hair testosterone concentrations were also claimed positively connected to risk taking in the case of hair's low cortisol in men [24]. As provided in the previous studies, the digit ratio (2D:4D) is believed as a proxy for testosterone exposure in utero. Many studies have been done to determine if there is any association between this ratio and economic preferences, or not.

There are always studies that challenge the mainstream beliefs about something or even prove something completely against them. For example, testosterone has been usually believed to affect economic decision making in individuals but some studies have found no significant relation between two variables Neyse *et al.* (2021) claimed that most of the previous studies have been done with small sized samples, and then they assessed this relation in a large sample of more than 3400 participants [25]. Economic preferences determined through validated survey questions were claimed to have no significant relation with the (2D:4D) ratio [25]. Stanton *et al.* (2021) in a three parts assessment, tried to find if testosterone is related with several different aspects of economic decision making. In a counter-balanced, double-blind, within-subjects design, they gave participants a booster of testosterone or placebo and after a delay to comfort drug uptake, people were asked to complete the decision-making tasks. As their results show, there is no solid relevance between testosterone and financial behaviors or preferences [26].

Progesterone and Estradiol

At the first decade of the current century, the association between hormone levels and human behavior has been a new hot topic with few reliable experimental works. Vermeersch *et al.* (2008) discussed the very little knowledge regarding the relation of sex steroid hormones relate and aggressive (ART) and/or non-aggressive teenager risk-taking (NART) behavior in girls. In a review study, they checked the association between serum concentrations of testosterone and estradiol as well as ART and NART. They reported (i) A relation between free estradiol and both NART and ART and (ii) no correlation between T and ART or NART [27]. Derntl *et al.* (2014) addressed the previous studies and discussed if personality factors such as sensation seeking, impulsivity, and anxiety are associated with decision-making, sex-specific effects, act as modulators is unclear. To measure the risk taking, all participants performed different tasks same as the BART, the Cambridge cognition task, the Game of Dice Task, and the Haegler's Risk Game (HRG). Estradiol, progesterone, and testosterone levels were assessed via the saliva samples provided by the subjects. The study reported no sex variations in decision-making and or any important effect of testosterone on behavioral performance in women or men. However, they claimed there is a major negative association between progesterone level of women in the luteal phase and their performance in the risk-averse status [28]. Drichoutis and Nayga, (2015) made an effort to check the claims about the biological underlying of economic behavior by particular

tracking if gender differences in risk/time preferences can be clarified by natural shifts in progesterone/estradiol levels during the menstrual cycle and by prenatal exposure to testosterone and estrogen levels. They used the multiple price list (MPL) procedure proposed by Holt and Laury (2002) for risk and time preferences. They claimed there is no influence of the menstrual cycle (and thereby, of related changes in progesterone and estradiol concentrations) or of the digit ratio (D4; D2) on either risk or time preferences [29]. Review articles provide us with a wide range of studies on the topic and this is what makes them important. Balzer *et al.* (2015) in a systematic review study aimed to assess what is known about the role of endogenous estradiol on human adolescent girls' mood and behavior. Through the assessing of the findings from 14 major studies they reported some consistency in findings for mood and estradiol concentration, with associations between estradiol and depression and emotional tone and risk taking [30]. Hormones concentrations have always been assumed to serve as proximal biological mechanisms underlying individual variations in risk taking. Kurath, and Mata, (2018) did a systematic literature search and non-aligned meta-analyses to determine the relation between endogenous testosterone, estradiol, and cortisol levels and risk-taking related constructs (i.e. risk-taking propensity, impulsivity, sensation seeking, and novelty seeking). They reported association between risk-taking constructs and testosterone also estradiol but not cortisol [31]. Strojny *et al.* (2021) explained that Oral contraceptives (OC) and endogenous female sex hormones in naturally cycling women (NC) are connected to many psychological factors including hormones. For social behaviors they used a social decision task which assesses trust, trustworthiness, sharing, punishment, and nonsocial risk behavior as a non-social control condition. The Multifaceted Empathy Test (MET) was used to assess cognitive and emotional empathy. Saliva samples were provided to check the level of progesterone and estradiol. Based on the underlying biological mechanisms, they reported lower progesterone levels in OC than NC women and a negative association between progesterone and trust on the trend level, but no correlations between estradiol and behavior. They concluded that OC moderates the social behavior and primary indications of a possible modulation by progesterone [32]. The current research is an experimental attempt to assess the effect of testosterone, cortisol, progesterone and estradiol on the financial risk taking. Total number of 37 participants including 17 women, provided blood samples in a clinical laboratory to measure the level of the hormones, they also were asked to fill a standard and reliable questionnaire provided by Grable and Lytton (1999) [33] to quantify the level of financial risk taking in them. After applying four regression models including Random Forest regression, Multi-Layer Perceptron, Gaussian Process regression, and Epsilon-Support Vector regression on the data set, the results demonstrated that the value of risk taking could be modeled in related to the testosterone, cortisol, progesterone, and estradiol levels.

The statistical experiments also show that except for testosterone, the other three hormones have negative associations with the value of risk taking in individuals. Testosterone concentration seems to have a positive relation with the risk taking.

Methodology

Measuring the Variables

As explained above, the level of hormones was measured in the blood sample of the participants in a clinical laboratory. Testosterone level was measured with IDS-iSYS analyzer through CL method; progesterone and cortisol concentration were measured with the Roche Cobas E411 analyzer which is an automatic system that uses Electrochemiluminescence (ECL) technology. Cortisol concentration has two peaks one at 8 AM and the other at afternoon about 4PM [34] which in the current study participants were ask to provide a fasting blood sample at 8PM to obtain the most reliable results of the cortisol level. The other hormones not have any preferred time or situation such as being measured in fasting blood

sample. Finally, estradiol was measured with Abbott via CL method.

The financial risk taking level of the individuals was determined through a questionnaire designed by Grable and Lytton (1999) which has been frequently used in many different studies before. It is a 20-item questionnaire form that considers different risk taking dimensions and elements which have influence on them and finally provides a score for each person as the level of financial risk taking. One would obtain the score of 20 as the minimum and 69 as the maximum. The degree of risk taking increases with higher the score. The blood samples were provided from 37 participants including 17 women and 20 men between 24 to 65 years old. The blood samples and the answered questionnaires were collected in a certified laboratory during 90 days started from October 1st to December 20th 2022.

The hypotheses of the current study are described as follow:

1. The risk taking score has a relation to the testosterone level.
2. The risk taking score has a relation to the cortisol level.
3. The risk taking score has a relation to the progesterone level.
4. The risk taking score has a relation to the estradiol level.

To show this, several regression methods are adopted to check if risk taking could be modeled by the mentioned hormones levels. These methods include: Random Forest regression, Multi-Layer Perceptron, Gaussian Process regression, and Epsilon-Support Vector regression. These regression models indicate acceptable estimation for risk taking with the values of four hormones assessed in the current study. Here, a brief explanation on the mentioned regressors is provided:

Random Forest (RF) regression is a forest of multiple decision trees constructed in a certain random way [35]. Decision trees are trained to obtain non-linear relationships between input variables and the target or output variable. Ensemble learning is utilized to average the results of all trees and produce single results. The number of estimators is the number of decision trees in RF model.

The Multilayer Perceptron (MLP) is a kind of artificial neural network applied widely to solve a range of variety problems, such as pattern recognition, regression, prediction, and interpolation [36]. The architecture of an artificial neural network consisted of an input layer, single, or multiple hidden layers, and one output layer. Figure 1 displays the architecture of the designed multi-layer perceptron network in this paper. There is a set of dense fully connected layers. The number of neurons per layer and the number of layers are defined experimentally. In the designed MLP architecture in this article, there are four neurons in the input layer to get hormone values and one neuron in the output layer to estimate risk taking values. Furthermore, there are two hidden layers with 40 neurons per layer.

Gaussian process regression (GPR) is a supervised, non-parametric Bayesian approach for solving regression problems [37,38]. GPR calculates the probability distribution over all proper functions that fit the data. It has a Kernel to compute the covariance between data points.

Support vector regression (SVR) is a supervised-learning approach specified using kernels and sparse solution [39]. Support vector machine creates a collection of hyper planes in a high dimensional space for systemizing problems which are represented in terms of support vectors. To map the data points into higher dimension, the kernel function is used. SVR is trained using a loss function and tries to fit as many data points as possible without violating the margin.

In the following section, the results are presented and the detailed discussion on the achievements is provided.

Machine Learning and Regression

Several experiments are made to evaluate the performance of regression models. These models are implemented using Python, Jupiter Notebooks, and Tensor flow and Scikit libraries. The mentioned four regression methods are

trained to model the score values using these two hormone levels. The models in this paper have been utilized for estimation with the following settings: In RF, the number of estimators is set as 40, in MLP, two hidden layers are considered with 40 neurons in each hidden layer and 1 neuron in the output layer, the optimizer is 'Adam', the batch size is 2, total number of epochs is 50, and the activation function is 'reLu'. In GPR, the Kernel function is defined as Dot product kernel plus white kernel. In SVR, the Kernel function is defined as RBF (radial basis function), the regularization parameter is 1, and the Epsilon value is 0.1.

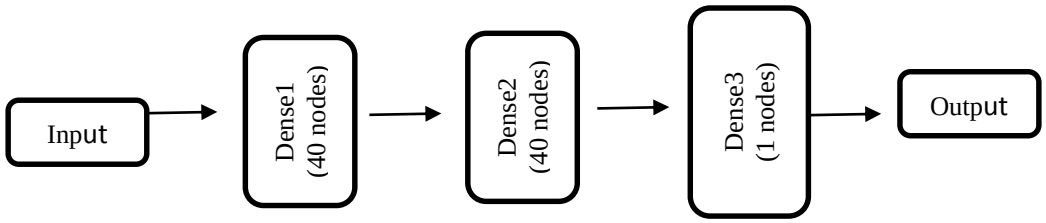


Figure 1: The architecture of the (MLP) network with dense layers for risk taking estimation

We use 80% of data for training the models and 20% of data for test. Train and test data are selected randomly. Results show that these features could be used for estimating the target scores. For training, data was normalized by applying min-max scaling. For MSE, RMSE, or MAPE calculation and evaluating the models, output results are re-scaled to the original range. The Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE) are used for comparing the performance of the regressors. They are calculated using Equations (1)-(3), where n is the size of data, A_t is the actual value, and P_t is the estimated value. The accuracy is defined as 100-MAPE.

$$\mathrm{MAE} = \frac{\sum_{t=1}^{n} |P_t - A_t|}{n} \quad (1)$$

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{t=1}^{n} (P_t - A_t)^2}{n}} \quad (2)$$

$$MAPE = \frac{100}{n} \sum_{t=1}^{n} \left| \frac{P_t - A_t}{A_t} \right| \quad (3)$$

All regressors were trained using the training data, and then the estimated values for train and test data were produced and compared with the actual values using comparison criteria.

Results

Results for the cortisol, progesterone, testosterone, and estradiol are presented in tables. Table 1 indicates Pearson's r correlation demonstrating the correlation between two variables. Tables 2 and 3 provide the results of estimation by each regression model separately for the train and test sets of data. Figure 2 depicts the actual values of scores in comparison with the estimated ones by the regressors. The first 30 samples are train data and next 8 samples are test data.

As shown in Tables 2 and 3, the SVR model in test data set with the accuracy of 90.12 has worked better than the other three models, whilst the GPR with the accuracy of 85.63 for train data set and 87.75 for the test data set have provided the least accuracy. The differences amongst the regression models are also clear in Figures 2 (a-d) which compare the estimated and actual values of scores associated with 4 hormones.

Discussion and Conclusion

As explained in the previous sections, the biochemical hormones change the human attitude toward different subjects including financial behaviors same as risk taking. This article is an experimental attempt to assess the effect of the levels of testosterone, cortisol, progesterone, and estradiol indicated in the blood sample on the financial risk taking score measured through a questionnaire. The Pearson's r correlation confirmed that the levels of four mentioned hormones are related to the level of risk taking and except of testosterone, the

other three hormones are negatively related with the risk taking level in individuals. Just testosterone showed a positive relation. Findings are consistent with a wide range of previous studies which assess the effect of the hormones on the brain function and behaviors.

Testosterone, cortisol, progesterone, and estradiol play roles in the sections of human brain which are related to sentiments and incentivization. These chemicals significantly affect financial decision-making closely associated to their primary biological functions, reproductive success and response to stress, respectively [40-42].

The data were also evaluated by the different regression models including Random forest regressor, Multiple Layer Perceptron regressor, Gaussian Process regression and Epsilon-Support Vector regression to provide reliable estimations. The final outcomes of data analysis were demonstrated via three statistic indicators RMSE, MAE, MAPE which are considered as comparison indexes. They show the difference between the real data and the data provided by the model. In other words, they specify the accuracy of the model. The main achievement of these experiments is that the risk taking value could be modeled in relation to the four mentioned hormones. Based on the results, SVR has the least error. Therefore, it is the most accurately utilized model in the current study.

This study is an experimental research which determines the relation between biochemical and financial behaviors in human. Such works would provide a more specific framework in the case of association between biochemistry and behaviors of human which is in the scope of different fields of sciences same as neuroeconomics, behavioral finance, behavioral economics, etc. Each study faces various difficulties and limitations which impact the interpretation of the findings. In the current study, the effects of four hormones are assessed on the risk taking whilst different hormones would affect the later variables same as dopamine and oxytocin which are highly related to risk attitude in human [43].

Table 1: Pearson's r for testosterone, cortisol, progesterone, and estradiol; as four features and the risk taking score as the target

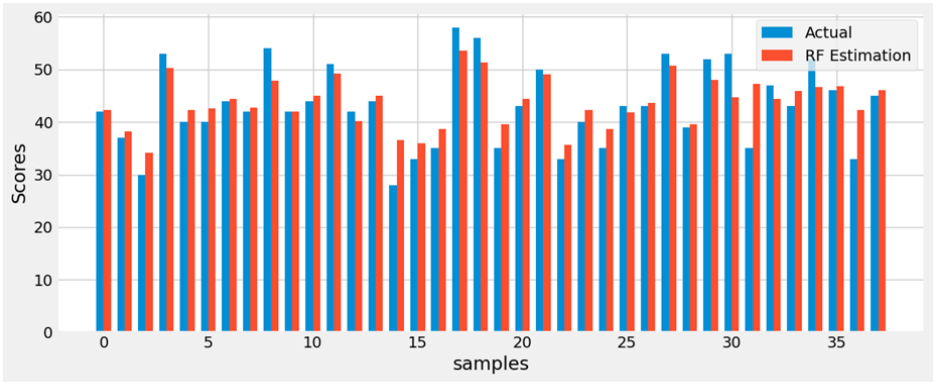
	Cortisol	progesterone	testosterone	estradiol
Pearson's r	-0.25804784	-0.09632822	0.20766376	-0.20352976

Table 2: Experimental results for train data

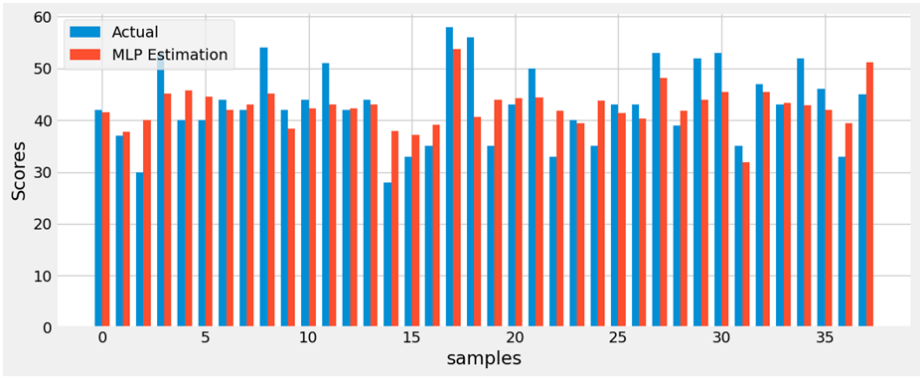
#	Model	Accuracy	RMSE	MAE	MAPE
1	Random Forest	93.72	3.14	2.49	6.27
2	MLP	87.99	6.15	4.91	12.00
3	GPR	85.63	7.32	5.87	14.36
4	SVR	86.07	6.41	5.63	13.92

Table 3: Experimental results for test data

#	Model	Accuracy	RMSE	MAE	MAPE
1	Random Forest	86.77	6.62	5.33	13.22
2	MLP	89.14	5.57	4.79	10.85
3	GPR	87.75	6.39	5.33	12.24
4	SVR	90.12	5.39	4.35	9.87



(a)



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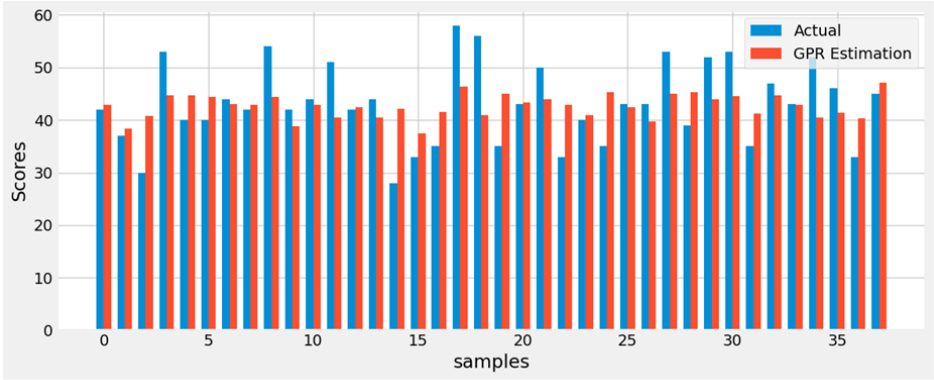

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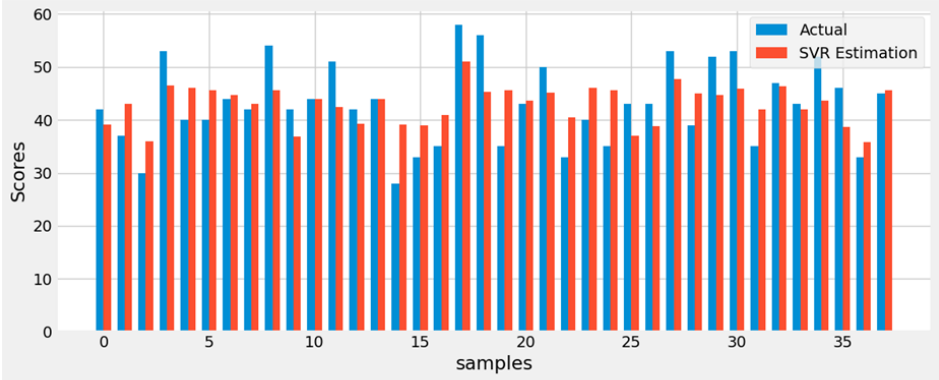

(d)

Figure 2: Schematic diagrams of the actual values of scores (as the target) in comparison with the estimated ones provided by the regressors of: (a) Random forest regressor, (b) MLP regressor, (c) GPR, and (d) SVR for four features which are the testosterone and cortisol hormones. In all regression models, the first 30 samples are considered as the train data and next 8 samples are considered as the test data for four features of cortisol, progesterone, testosterone, and estradiol

Despite of the utilized regression models in this study, different neural network algorithms same as ANFIS, NNAREX, and AdaBoost have shown high accuracy in estimation and prediction and in the future studies, these methods can be utilized [44]. Provides a brief description on the architecture and application of the mentioned models. In this study, monetary difficulties caused us to have a relatively small number of participants whilst by the financial support of the educational departments there would be a great number of contributor and therefore the more reliability of the findings.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

Authors' Contributions

All authors contributed toward data analysis, drafting, and revising the paper and agreed to responsible for all the aspects of this work.

Conflict of Interest

The authors declare that they have no conflicts of interest in this article.

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