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# The Impact of Exercise, Diet, and Meditation on Cognitive Function, Prefrontal Hemodynamics, Functional Connectivity, and Biochemical Parameters

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## Abstract

Exercise, diet, and meditation enhance physical wellness and psychological well-being, commonly boosting productivity. However, their specific effects remain limited. This study assessed these methods using cognitive changes, prefrontal cortex blood flow, brain connectivity, key blood parameters, and daily self-assessments of 46 middle-aged Indo-Europeans (22 women) engaged in intermittent fasting, cardio-strength training, or daily meditation for 8 weeks. The meditation group showed significant improvement in executive function, with an increase in task-switching reaction time (255.22 ± 317.20 ms) and enhanced heart rate variability. There was a significant decrease in creatinine concentration (5.04 ± 0.89 g/dL) and an increase in zinc concentration. The diet group experienced a significant decrease in brain oxygenation (−2.48 ± 2.50 of TSI) and an increase in leptin levels (2.15 ± 0.04 g/dL). Over 60 min of daily physical activity correlated with quicker responses. All groups demonstrated improved attention compared to controls, with decreased inhibition latency (meditation: 12.97 ± 41.99 ms, diet: 9.90 ± 49.07 ms, exercise: 16.38 ± 49.07 ms). Meditation and exercise groups showed reduced connectivity across six frequency bands. Serotonin levels dropped notably in the diet group (99.02 ± 7.04 g/dL). After 2 months, exercise and meditation showed greater benefits than diet or controls.

***Keywords***: electroencephalography; functional near-infrared spectroscopy; functional connectivity; cognitive functions; meditation; diet

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## Introduction

Work productivity significantly impacts quality of life and well-being. It is influenced by various factors including chronic diseases, depression, infectious diseases, and conditions such as chronic pain, chronic fatigue, and shift work (Okdeh et al., 2023; Picard & McEwen, 2014). However, the precise effect of daily habits on human performance and physiology remains incompletely understood (Harrington, 2001; Yetton et al., 2019).

With increasing confidence, exercise, diet, and meditation are recognized as simple yet effective methods for enhancing well-being and achieving a healthy, productive life (Arya et al., 2018; Borchardt & Zoccola, 2018; Mattson et al., 2017; Reimers et al., 2018). However, there is still no overarching evidence demonstrating conclusively that these activities improve cognitive function or brain performance due to incomplete understanding of their underlying mechanisms (Chiesa et al., 2011; Kuczmarski et al., 2014; Northey et al., 2018).

The measurable physiological markers of work productivity and performance remain difficult to find, though they are believed to be cunningly connected to cognitive functioning. Previous research indicates that cognitive complexity, stress, and uncertainty directly impact task performance and can indirectly influence overall productivity and occupational safety (Jahncke et al., 2011; Kikkawa et al., 2023; La Torre et al., 2019; Reganova et al., 2023; Woods & Dekker, 2000). Given the physiology of cognitive functions, neurotransmitters are considered potential candidates for estimating cognitive performance as they play critical roles in cognitive functioning (Garcia-Esparcia et al., 2018; Volk et al., 2015). However, it's important to note that neurotransmitters produced in the neural system may not always be accurately reflected in blood serum or cerebrospinal fluid (CSF) levels, which may not fully represent neural status (Bak et al., 2006).

On the other hand, numerous widely measured biochemical blood markers have been proven to be connected to the level of cognitive functioning (Jensen et al., 2015; Popiołek et al., 2020). Biochemistry blood test data used to be limited to clinical applications, but in the last decade, it has been routinely used in many professional settings as a physiological monitoring tool, for example, to define aging markers (Engelfriet et al., 2013). Such an approach provides relevant information including identification of inflammation processes, as well as the levels of macronutrients and vitamins, oxidative stress, and energy deficiency. Regular blood tests can be used to monitor personal efficacy or analyze the efficacy of various interventions, such as physical exercise, nutritional strategies, mental training, etc. One of the main challenges in using biomarker data is the wide interindividual variability. There is also a lack of longitudinal observations of biomarkers on certain populations. Therefore, external influences (e.g., seasonal) can also affect the data. With the help of the profiling and monitoring approach, biochemical blood marker measurement combined with contextual personalized data has the potential to improve the quality of life of the general population, enhance and partially test the application of 4P healthcare principles (i.e., predictive, preventive, personalized, participative) in daily life, and collect information for further fundamental and practical studies on human health and telemedicine.

One potential blood parameter for assessing cognitive performance is creatinine. Previous studies have indicated that higher serum creatinine levels are associated with better overall cognitive performance, short-term working memory, and episodic memory, as well as associative learning in middle-aged men (Hakala et al., 2022). Additionally, other research suggests that creatinine supplementation in food may also improve short-term memory, intelligence, and reasoning (Avgerinos et al., 2018). Uric acid's antioxidant properties can have beneficial effects, especially in the context of neurodegenerative diseases. Recent research indicates that uric acid may provide neuroprotective effects in Alzheimer's disease and Parkinson's dementia. Hypouricemia is considered a risk factor for accelerated disease progression and may serve as a potential marker of malnutrition. Conversely, elevated serum uric acid levels may have a detrimental impact on the course of vascular dementia (Tana et al., 2018). Zinc plays a critical role in the nervous system (Bhatnagar & Taneja, 2001), functioning as a neurotransmitter and second messenger. It takes part in regulating hippocampal long-term potentiation, enhancing neuronal survival, and facilitating learning and memory processes (Choi et al., 2020). Various neurotransmitters offer valuable insights into cognitive function. For example, decreased extracellular levels of 5-HT (serotonin receptors) have been linked to impaired memory consolidation (Cowen & Sherwood, 2013). Furthermore, the significance of noradrenaline in numerous cognitive processes, such as vigilance, attention, learning, and memory, is well established (Holland et al., 2021). Dopamine receptors in the prefrontal cortex control three key aspects of cognitive control—gating, maintaining, and relaying (Pillon et al., 2003). Leptin, the prototypical adipokine, expresses receptors across the cortex and various other brain regions. While predominantly investigated for its involvement in regulating energy intake and expenditure, leptin plays a pivotal role in numerous neurocognitive processes. It interacts with a range of hormones and neurotransmitters to fulfill these functions (Farr et al., 2015). Indeed, leptin influences hippocampal-dependent learning and memory, and more recently leptin has been shown to have antidepressant properties (Harvey, 2007).

The research data provides a diverse set of methods for improving cognitive performance, including physical and cognitive exercise (Moniruzzaman et al., 2020), mindfulness practices (Cifu et al., 2018), and intermittent fasting (Ooi et al., 2020). These interventions have demonstrated effects on both cognitive performance and biochemical blood parameters. For instance, recent studies have shown that physical fitness levels are associated with performance in attention, memory, spatial imagery, reaction speed, and executive functions such as cognitive flexibility and inhibition control (Chang et al., 2012; Pontifex et al., 2012). Moreover, a high testosterone-to-cortisol ratio suggests greater anabolic drive and has been strongly associated with positive training and performance outcomes (Pedlar et al., 2019), while low iron status compromises the erythropoietic effects of altitude linked to endurance performance (Garvican-Lewis et al., 2018). Recent studies indicate that physical activity and exercise play a significant role in preventing and mitigating symptoms of depression (Agbangla et al., 2023; Danielsen et al., 2023; Jacinto et al., 2023; Josefsson et al., 2014; Rosenbaum et al., 2014; Sachs et al., 2023; Schuch et al., 2016) and may have antidepressant effects in individuals with neural system-related conditions (Adamson et al., 2015).

Several studies suggest that regular physical exercise enhances daily performance by promoting better stress adaptation, reducing anxiety (Knöchel et al., 2012), and fostering the development of social skills (Erickson et al., 2011), memory (Winter et al., 2007), and creative thinking (Oppezzo & Schwartz, 2014). These observed effects are believed to be associated with exercise-induced neuronal adaptations and the interplay of monoamines (Acworth et al., 1986; Guillouzo & Guguen-Guillouzo, 1986). Additionally, another study revealed a significant improvement in cognitive flexibility among participants undergoing aerobic training for 10 weeks, with no significant changes observed in attention and mental speed (Masley et al., 2009). Moreover, aerobic exercises positively influence the connectivity of the default brain and executive control networks, as well as synchronize brain regions associated with reward and attention (Voss, Erickson, et al., 2010; Voss, Prakash, et al., 2010; Weng et al., 2017). Conversely, research investigating the effects of exercise on motor coordination in adults is relatively limited compared to aerobic exercise's impact on cognitive functions. One notable study demonstrated that motor coordination training yielded better results in reducing task-switching costs compared to cardiovascular training (Johann et al., 2016).

The effects of dietary restrictions on cognitive function have been extensively studied in recent years; however, the findings have not consistently demonstrated a clear pattern (Dias et al., 2020). The lack of consistency can be explained by variations in experimental protocols, leading to contrasting cognitive outcomes. For instance, in one study, it was reported that ketone-fed rats exhibited a 38% faster completion rate in an 8-arm radial maze test compared to those on other diets and made more correct decisions before errors occurred (Murray et al., 2016). Conversely, another study found that ketone-fed rats experienced severe impairments in visual-spatial memory and decreased brain growth (Zhao et al., 2004). In experiments with mice subjected to intermittent fasting, improved learning and memory capacities were observed based on Barnes maze and fear conditioning assessments, along with a thicker CA1 pyramidal cell layer, when compared to mice with unrestricted access to a regular diet (control mice; Li et al., 2013). Additionally, older adults with mild cognitive impairments who regularly practiced intermittent fasting showed better cognitive scores and displayed a reversal in cognitive function improvements over a 36-month period (Ooi et al., 2020). However, a separate pilot study in humans reported a decrease in cognitive function, as assessed by the Montreal Cognitive Assessment, and short-term memory in the intermittent fasting group (Christensen, 1974). Despite the indirect effects of intermittent fasting on neuroplasticity and neuroprotective functions for both animals and humans having been detected, few studies have investigated changes in specific patterns of activation and functional connectivity within brain networks (Mattson et al., 2018; Murphy et al., 2014).

Systematic reviews of various types of meditation have reported preliminary positive effects on cognitive functions, including attention, memory, executive function, processing speed, and general cognition (Chiesa & Serretti, 2009; Dharmawardene et al., 2016; Gard et al., 2014; Goyal et al., 2014; Moore & Malinowski, 2009; Newberg et al., 2010). These beneficial effects are believed to be partially attributed to stress reduction. Additionally, longitudinal mind-body practices have been associated with gene expression changes related to inflammatory pathways and increased telomerase activity (Jacobs et al., 2011; Zhu et al., 2012).

Comparative analysis has revealed distinct differences in the functional connectivity of the brain between more experienced and less experienced meditators, as well as changes in connectivity patterns among novice meditators. Specifically, participants with greater meditation experience exhibited increased connectivity within attentional networks, as well as between attentional regions and medial frontal regions (Hasenkamp & Barsalou, 2012). During resting-state, meditators demonstrated greater resting-state functional connectivity (rs-FC) within the dorsal attention network (Froeliger et al., 2012).

To explore changes in metabolism during cognitive tests after exercise, functional near-infrared spectroscopy (fNIRS) is often employed. Comparing the activity of the prefrontal cortex during meditation using fNIRS suggests that oxygen consumption in the right prefrontal cortex is increased during meditation compared to the resting state (Deepeshwar et al., 2015). At the same time, the effect of regular meditation on brain activity while solving cognitive tasks has not been sufficiently studied.

The interpretation of the impact of these interventions is challenging due to several factors, including variations in the duration of interventions, participant demographics (age, gender, etc.), and the parameters measured. Although a growing body of evidence indicates a positive cognitive effect of the mentioned above practices, comparing their effects remains difficult due to differences in experimental designs. In our study, we sought to compare the effects of 8 weeks of regular physical exercise (either high-intensity interval training or strength training), intermittent fasting, and meditation on cognitive performance and physiology parameters.

Based on previous data, we formulated the following hypotheses:

1. Both meditation and exercise will enhance memory, attention, and cognitive flexibility while reducing biochemical markers of the stress.
2. During cognitive tests, we expect higher oxygenation levels in the right prefrontal cortex for meditators and in the left prefrontal cortex for the exercise group after 2 months of training.
3. Regular meditation might result in an increase in global connectivity, and exercise may lead to the redistribution of connectivity patterns.
4. Intermittent fasting could enhance cognitive performance through increased mitochondrial activity throughout the body.

By examining these interventions' effects on cognitive performance and physiological parameters, our study aims to contribute valuable insights into their potential benefits and mechanisms of action. Addressing these hypotheses will help bridge gaps in understanding the impact of these practices on cognition and overall well-being.

## Materials and Methods

### Participants

Sixty healthy, right-handed Indo-European adults aged 25 to 50 were recruited to participate in the study. They were randomly and evenly assigned to four different groups. However, at the start of the study, two participants from the diet group dropped out, and one requested to be transferred to another random group. Consequently, 46 participants (22 women, mean age 33.4 ± 7.7 years) completed the study: 14 in the meditation group, 8 in the diet group, 16 in the exercise group, and 8 in the control group.

Participants meeting the following criteria were included: (a) no prior regular practice of meditation, intermittent fasting, or exercise. Through interviews, it was confirmed that none had practiced intermittent fasting, attended meditation classes, or engaged in regular exercise over the past year. Moreover, none had participated in vipassana or held a degree in sports; (b) normal health as determined by routine clinical examination, with a BMI ranging from 18 to 25. Individuals on medication or dietary supplements and those with medical records of mental or cognitive disabilities were excluded from the study. Participants with infectious diseases during the 8-week study period were excluded from the analysis.

The study protocol and the nature of the experiments were explained to the subjects before obtaining signed informed consents. Each subject signed the consent form for routine medical monitoring, including the statement of agreement for the use of the results for scientific purposes. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of I. M. Sechenov First Moscow State Medical University (protocol No. 28-19 on 18.11.2022).

## Training Protocols

All activities lasted for 8 weeks. Daily throughout the study, participants reported their activity parameters in a telegram bot: sleep time, heart rate, total training duration, the number of steps, the time of the last meal, and a subjective assessment of well-being. The main goal of all groups was to follow the training program in a disciplined manner. The regularity of the exercise and meditation was checked by collecting heart rate samples from workouts and meditation sessions. The quality of the diet plan was assessed from the participants' daily reports.

***Meditation (M).*** The participants in this group practiced twice a day, for 15–20 min in the morning and the evening. Each session included a warm-up exercise for the eyes, alternating breathing of the left and right nostrils (anuloma-viloma) for 5 min, and 22 long breaths with a focus on sensing their nostrils.

***Intermittent Fasting (D).*** Participants in the diet group alternated 1 week of 8/16 intermittent fasting (16 hr of fasting every day) with 1 week of the low-carb diet between weeks of the cycle: Week 1 – 8/16 intermittent fasting, Week 2 – low carb diet, Week 3 – 8/16 intermittent fasting, and so on for 8 weeks in total. All participants received detailed verbal and written instructions on the diet plan and a list of recommended products.

***Exercise (E).*** The exercise group members trained three times a week according to a prewritten program. The training included a 5–10 min warmup of cardio-aerobic exercises, 20 min of static-dynamic training, 10–15 min of cardio-aerobic training, and 10 min of stretching. Static-dynamic training consisted of strength training for the thigh, lower leg, abdomen, back, chest, shoulder and gluteal muscles. The complete training protocol, including the number of repetitions, can be found in the Appendix B.

## Measurements

To comprehensively study the influence of trainings, we measured a diverse array of metrics, including four cognitive tests, tissue saturation indexes (TSI) obtained through fNIRS, EEG functional connectivity analysis, biochemical blood tests, recurring daily reaction time assessments, heart rate variability (HRV) parameters, daily step counts, and sleep efficiency measurements.

***Cognitive Tests.*** All participants performed cognitive tasks with simultaneous measurements of brain activity with EEG and fNIRS taken twice: before the onset of the training process and immediately after (8 weeks after the first measurement). Each test lasted for about 30 min and included the following parts: 1 min resting state with eyes open, 1 min resting state with eyes closed, and four cognitive tests: Corsi test, Iowa gambling test (IGT), stop signal test (SSt), and task switching test (TSt; standard protocol tests from platform https://www.psytoolkit.org; Stoet, 2010, 2017). These tests were selected to check the performance of such cognitive domains as working memory/attention and executive function (Cullen et al., 2007). We did not consider the change in verbal memory, visual construction or abstract reasoning, based on other research (Kuczmarski et al., 2014; Northey et al., 2018) and because of the time limit for subjects sitting comfortably during the test. Based on the test results, we evaluated the following parameters: the maximum length of the memorized sequence and the rate of correct answers in the Corsi test for working memory, the percentage of selecting the low-risk variations in the Iowa gambling test, the cost of switching in the TSt and the inhibitory latency, the accuracy, and the time rate of correct answers in the SSt. The Corsi test included 10 presentations of sequences of up to 10 elements; SSt included 90, TSt 120, and IGT 100 stimulus presentations, respectively.

***FNIRS.*** Measurements were conducted with NIRS4 brain and body spectrometer (Medical Computer Systems Ltd., Moscow, Russia) using two 4-channel arrays of optodes (one light source/emitter and four detectors in each device) covering the frontal and prefrontal area. Each device was square-shaped, with a diagonal length of 5 cm. At the vertices of the square there were detectors and a source in the center. The device was installed in such a way that the diagonal of the first square fell on the positions F6 and Fp2, and the diagonal of the second square fell on the positions F5 and Fp1. Near-infrared light was used at two wavelengths (770 and 850 nm). Changes in the concentration of oxygenated (O2Hb) and deoxygenated hemoglobin (HHb) were recorded continuously throughout the task with NIRSSensLSL Software. Signals obtained from the eight NIRS channels were acquired with a sampling rate of 10 Hz. The raw optical density signals were converted to hemoglobin concentration changes (in mmol/mm) using the modified Beer–Lambert law in MATLAB (adapted NIRS to HbH, HbO, TSI Brainstorm functions). TSI is defined as a ratio between oxygenated and total hemoglobin:

$$HbT = HHb + HbO$$
$$TSI = \frac{HbO}{HbT} * 100\%$$

The hemodynamic values corresponding to each cognitive test were calculated as the difference between the TSI averaged over eight sensors and the time of the test, and TSI averaged over eight sensors and 1 min with open eyes and no task.

***Electroencephalography (EEG).*** To study functional connectivity, we considered the EEG internode coherence. The coherence of two signals depends on their phase difference. Maximum coherence occurs when the phase difference is fixed between two signals. The coherence is zero (or near to zero) if the phase difference between two signals is random during time. Coherence is considered as:

$$coh_{ij}^2(w) = \frac{E\left[C_{ij}^2(w)\right]}{E[C_{ii}(w)] * E\left[C_{jj}(w)\right]}$$

where $C_{ij}(w)$ is Fourier transform of the cross-correlation between EEG nodes (node i, and node j) and $C_{ii}(w)$ is co-spectrum. Coherence was calculated in 10-s overlapping windows in the frequency domain, and then the coherences of all epochs were averaged over time.

All EEG signals were recorded with a NeuroPlay-8Cap (ltd. Neuro-assistive technologies; Moscow, Russia) using 8 surface electrodes (F3, F4, C3, C4, P3, P4, O1, O2) mounted on a cap following the International 10–20 positioning system. The ground and reference electrode was A2. There were dry electrodes, the electrode impedance was kept less than 100 kΩ. This impedance is acceptable for dry electrode systems (Higashi et al., 2017; Shad et al., 2020). All data were digitized in continuous recording mode (125 Hz sampling rate). The data was preprocessed via scipy toolbox for python. The zero mean EEG data of each subject is preprocessed using a band pass filter in 0.5–48 Hz for removing the artifacts. The signal was divided into 1-s epochs, and all epochs in which the signal amplitude exceeded 100 $\mu V$ were excluded. When the subjects were familiarized with the test conditions, the EEG was not recorded. EEG recording for analysis was carried out continuously throughout the test from the moment the start button was pressed until the end of the test. The division of the signal into epochs was carried out only for the purpose of clearing the signal. For further signal processing, spectral bands were used: delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta1 (12–18 Hz), beta2 (18–30 Hz), and gamma (30–48 Hz). The relative spectral power was considered as the proportion of the power in a given band to the entire spectrum. Frontal characteristics were calculated using electrodes F3, F4, C3, and C4. Interhemispheric connectivity was considered as the average connectivity between pairs of electrodes C3-C4, P3-P4, C3-P4, and C4-P3. Sagittal connectivity was considered as the average connectivity between pairs of electrodes F3-O1, F4-O2, F3-O2, and F4-O1.

***Physiological Metrics: Blood Tests, HRV, Activity, Sleep.*** All participants used triaxial accelerometers to measure motion. The obtained data was used to estimate physical activity, sedentariness, and sleep quality. For consistency of the obtained results, HRV metrics were measured with the help of Welltory (https://welltory.com), an application which uses photoplethysmography and electrocardiogram measurements taken with BLE heart rate monitors like Polar, Apple Watch, Fitbit, and mobile phone's camera. In this study, we collected physical activity levels including daily step count, active time, and sedentary time. Fitbit automatically deems the period of time active when a physical activity of at least three metabolic equivalents are performed. Sleep-related information is generated, including total time in bed, total sleep time, and awake time. Sleep efficiency was calculated as the combination of sleep duration and subjective fatigue feeling. Heart rate and HRV were measured every day at the same time of the day (in the morning or the evening).

A Telegram chatbot was used to send reminders to the participants and to collect daily productivity data. Only the data from the users who filled in more than 80% of the questionnaires was analyzed (*n* = 45). Most of the missed measurements were observed during the weekends (45% of missed questionnaires). Productivity was subjectively assessed by the participants themselves. Reaction time was measured based on the results of online test completions (https://humanbenchmark.com/tests/reactiontime).

Blood samples were collected in the morning from the antecubital vein into the clot activator tubes on Week 1 and Week 8. The investigable parameters were creatinine, uric acid, ALT zinc, testosterone, homocysteine, adrenaline, noradrenaline, serotonin, leptin, and dopamine. To eliminate interassay variance, all samples were analyzed in the same laboratory using the same methods.

***Statistical Analysis.*** The obtained data were analyzed for normality of distribution using the Shapiro-Wilk's test. Since not all studied parameters appeared to be normally distributed, we utilized the nonparametric (Vickers, 2005) Wilcoxon's test to compare the groups. Comparable values were in the form of differences between values at the end of the experiment (after 8 weeks of training) and at the beginning. To assess changes in cognitive test scores, TSI of fNIRS, and rhythmic characteristics and parameters of EEG functional connectivity, we employed a one-way ANOVA test. Post hoc Tukey criteria were applied for multiple test correction. The relationship between the values of various biochemical parameters and daily measurements was examined using the Pearson correlation coefficient. The values are presented as mean ± *SD*, with a *p*-value less than .05 considered statistically significant. All statistical analyses were conducted using the scipy.stats package in Python.

Additionally, a priori and post hoc analysis were performed using the G*Power 3.1.9.7 software (Faul et al., 2007). Considering four groups with two repeated measures, a large effect size, an alpha error probability of .05, and a high power ($1 - \beta > 0.85$), the required sample size for both ANOVA (repeated measures) and Wilcoxon's test was determined to be 40 participants. With an alpha level of .05, the current sample size, and the effect size calculated for this study, we achieved adequate power ($1 - \beta > 0.8$) for most characteristics, except for a few noted in the results tables.

## Results

### Cognitive Tests

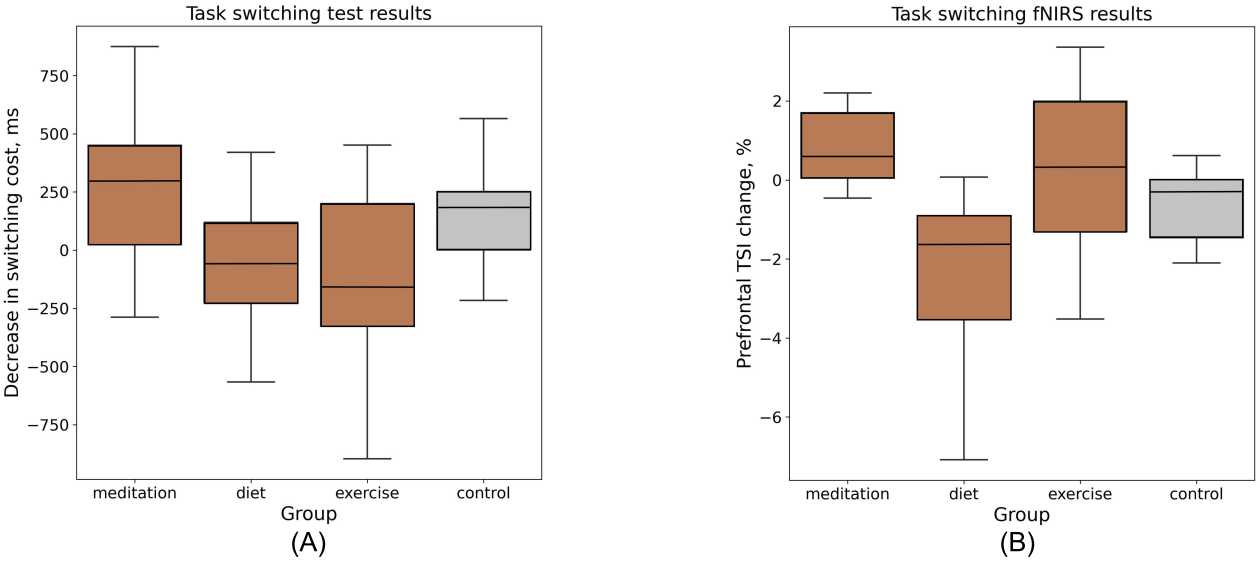
For all types of data described in the measurement section, we compared changes in results for different types of impacts (groups: M, D, E, C). No significant correlations were found between data of different types. There were no significant differences across four groups in changes in the Corsi working memory metrics and IGT decision-making. However, it was observed that the inhibitory latency was significantly improved for M, D, and E groups as compared to C (Appendix Table A1), according to the SSt. There were no differences between the groups in the accuracy and speed of reaction in SSt. In addition, the M had significantly improved the executive function after two months of training compared to the E and D groups (Appendix Table A2). The executive function was assessed via the cost of switching between tasks in TSt (Figure 1A).

Significant differences in 2-month changes in hemodynamics of the prefrontal cortex area, as indicated by fNIRS data, were observed in the TSt task: the M group showed significantly higher changes compared to both the D and E groups (see Appendix Table A2 and Figure 1B). Similarly, in the Corsi test, the M group showed more significant changes than the D group (see Appendix Table A3), and in the Iowa Gambling Test (IGT), the C group obtained higher changes compared to the D group (see Appendix Table A4). Thus, significant differences were only found for the TSt task in both test scores and changes in hemodynamics (see Figure 1B). Notably, 2 months of beginner meditation yielded better results for executive function and prefrontal cortex oxygenation during the TSt task compared to 2 months of intermittent fasting.

### Electroencephalography

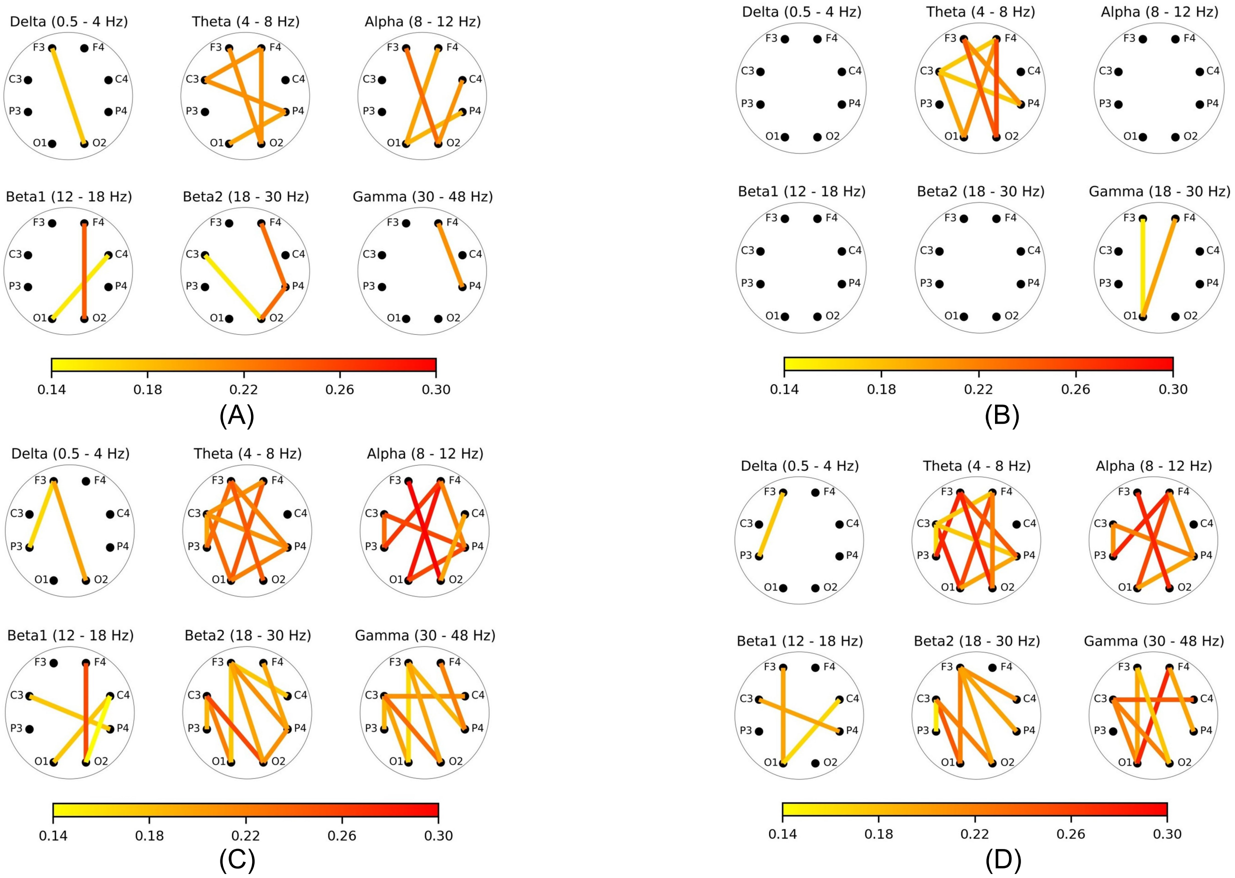
In the resting state with opened eyes no significant differences in absolute or relative spectral powers were found. However, there was a significant decrease in sagittal coherence for the meditator group compared to the diet (in theta and alpha bands) and control (in theta frequencies) groups. A significant decrease in coherence was also found for the E group: sagittal (theta, alpha), interhemispheric (theta, beta2), and left hemispheric (theta), in comparison to the D and C groups. In addition, the E group had a significant decrease in mean alpha, left and right hemispheric alpha coherence compared to the diet group, and a decrease in mean theta and left hemispheric beta1 compared to the control group (Appendix Table A5). A detailed comparison of rs-FC is depicted at Figure 2. Each part of the figure illustrates the significant differences in coherence changes for pairs of groups in the rs-FC between electrodes: (A) D-M groups, (B) C-M groups, (C) D-S groups, and (D) C-S groups.

**Figure 1.** *(A) TSt Results by Groups. (B) Changes in Prefrontal Hemodynamics During the Solution of the Task Switching Test by Groups.*



**Note.** (A) The vertical axis shows the decrease in switching cost in ms. Switching cost for M is significantly higher than for D and E groups. (B) The vertical axis shows the change in TSI in percent. Change in TSI for M and E is significantly higher than for D group.

**Figure 2.** *Significant Differences in Changes for Pairs of Groups in the rs-FC. (A) D-M Groups, (B) C-M Groups, (C) D-S Groups, (D) C-S Groups.*

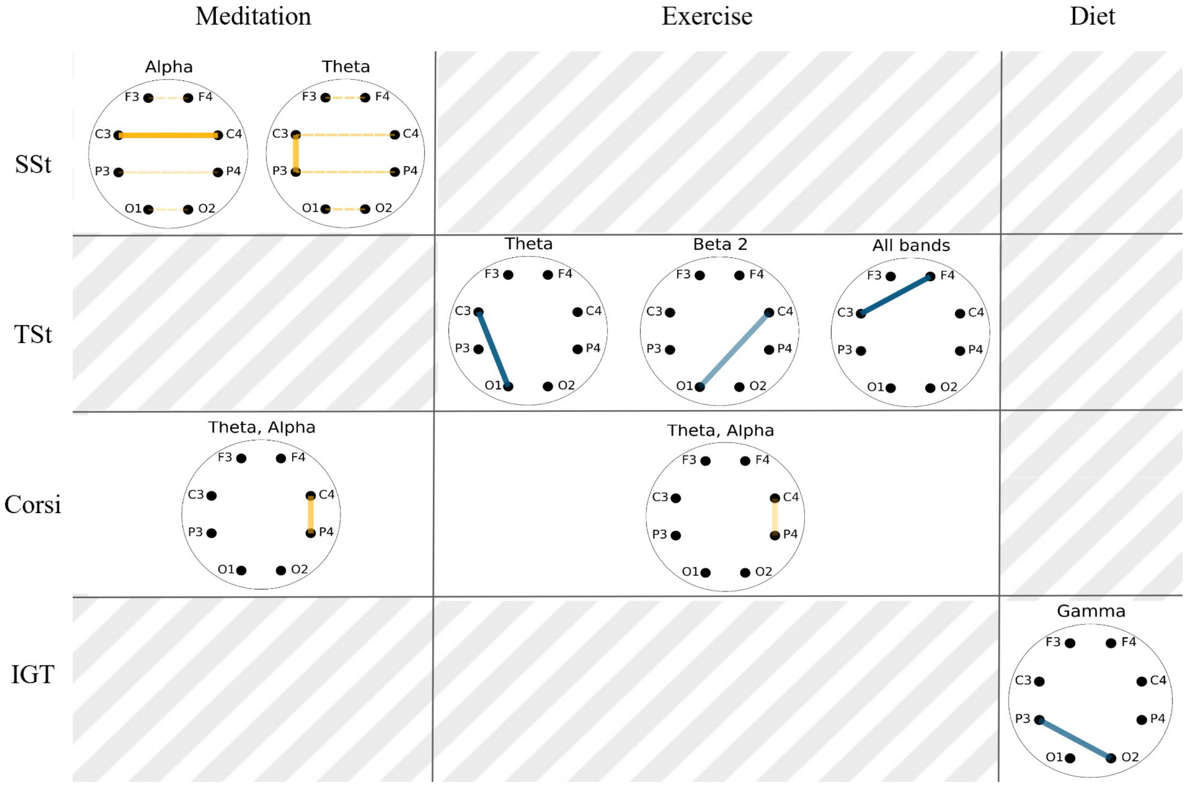


The pattern in FC during the test execution differs from the resting state. For M, compared with the E and C groups, interhemispheric coherence in theta and alpha significantly increased during SSt (Appendix Table A1). There was also a significant increase in the connectivity between electrodes C3 and C4 in theta and beta2 ranges in the meditation group compared to the E group during TSt (Appendix Table A2). Other single connectivity changes can be found in Appendix Tables A1–A4. Significant spectral changes were observed only for the Corsi test in the beta ranges (Appendix Table A3). All changes in comparison to the Control group are illustrated in Figure 3.

## Biochemical Parameters

Creatinine concentration changed significantly in the meditation group and the difference was reckoned 5.04 ± 0.89 g/dl. Uric acid concentration also increased significantly in the meditation group and was 8.15 ± 1.62 g/dl, whereas in the other three groups it decreased and was 19.30 ± 6.29 g/dl and 19.37 ± 5.44 g/dl in the functional training group and the fasting group respectively. Notably, we also observed a significant decrease in uric acid level in the control group, which amounted to 18.71 ± 7.12. Testosterone level remained the same in all the observed groups. Leptin increased significantly in the fasting group to 2.15 ± 0.04 g/dl. Regardless of the intervention type, serotonin decreased significantly in all the groups. It must be noted that the most dramatic decrease of serotonin was observed in the fasting group and the difference was estimated as 99.02 ± 7.04 g/dl. The meditation group also demonstrated a significant increase in zinc blood concentration, while the fasting group had increased norepinephrine concentrations. However, as for the rest of the observed differences, statistical significance could not be established for any of the parameters before and after the study.

**Figure 3.** *Significant Differences in Changes of FC In Comparison to the Control While Solving Different Tests (Which is Represented by Different Rows and Different Columns Correspond to Training Type).*



**Note.** Blue lines mean negative values, yellow lines are positive. Transparency characterizes the absolute values of changes.

## Daily Measurements

We observed a relationship between the intensity of training and reaction time in the exercise group. On days with high physical activity, participants reported fatigue more frequently compared to days with low physical activity (see Figure 4A). Furthermore, when comparing observed groups, we found a decrease in the number of daily steps in the fasting group compared to the control group (Figure 4B).

Sleep efficiency, defined as a function of sleep duration and subjective perception of fatigue reported by participants, correlated well in most participants. We noted a significant difference in sleep efficiency within the fasting group. Interestingly, participants with low sleep quality in this group did not report fatigue as expected.

We did not find significant changes in HRV parameters for the Diet or Exercise group. However, the values differed significantly in the meditation group when comparing values from the last week to the first, and moreover, after and before meditation (Figure 5).

**Figure 4.** *(A) Changes in Reaction Time After Training Session Depending on its Duration. (B) Average Number of Steps Per Day by Group.*

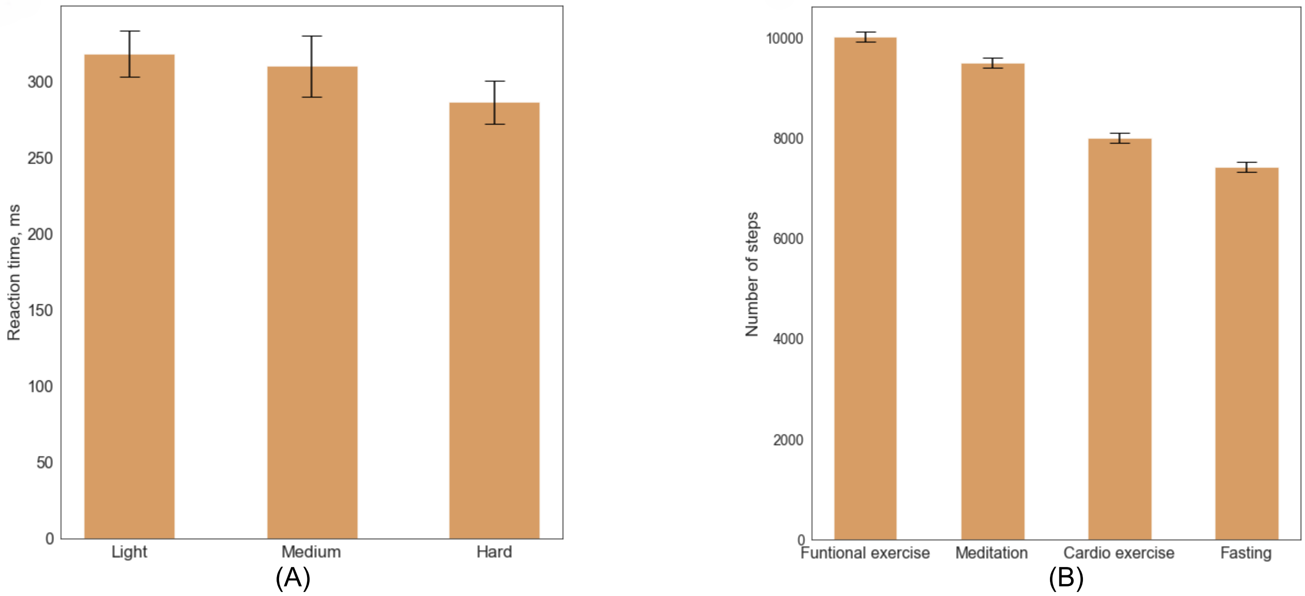
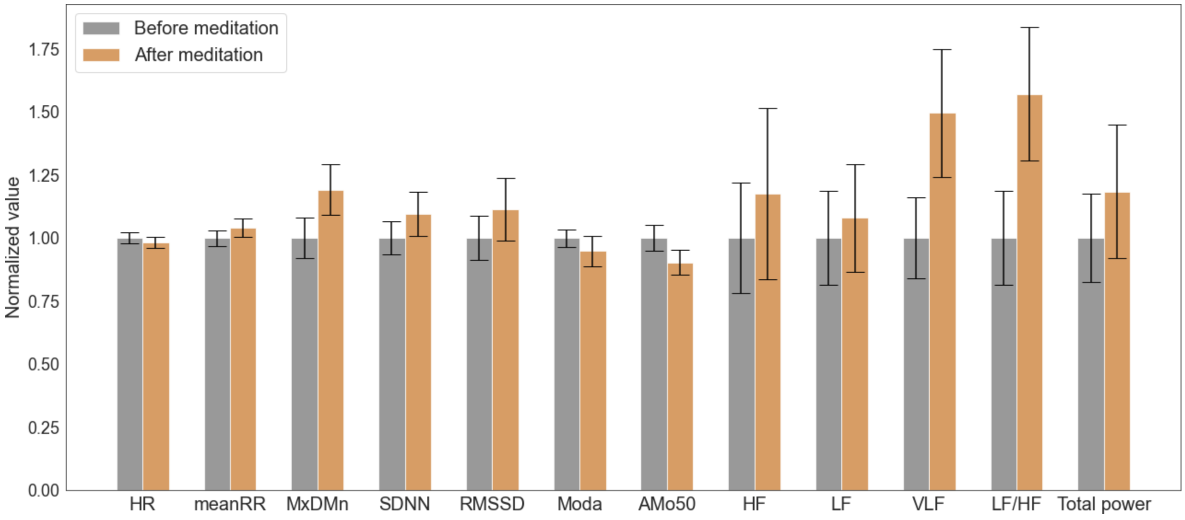


**Figure 5.** *Changes in HRV Parameters After Meditation Practice.*



**Note.** All values were normalized on the corresponding values before meditation.

## Discussion

Our findings demonstrate that all types of the studied interventions, meditation, diet, and sports, positively affect the reduction of inhibitory latency equally in comparison with the control group, which is quite consistent with previous studies (Chang et al., 2012; Pontifex et al., 2012). We also reveal that different types of activity have different effects on cognitive function and patterns of brain activity. Specifically, we have shown that in order to increase the executive function, 2 months of meditation may be more effective than sports and diet for beginners. Based on the literature review, no similar comparison was carried out, although an increase in executive function was shown separately for meditation and sports (Gard et al., 2014; Moore & Malinowski, 2009; Newberg et al., 2010).

Other researchers have repeatedly noted the connection between cognitive load in solving intellectual tasks and an increase in oxygenation in the prefrontal cortex (Causse et al., 2017; Verner et al., 2013). Although the current study did not find direct correlations between these indicators, the intergroup changes are in good agreement with the above trend. For example, according to the TSt in the group of meditators compared to the diet group, the results of the test itself and the level of oxygenation of the prefrontal cortex are significantly higher.

Overall, we observed a decrease in prefrontal cortex oxygenation in the dietary group compared to the control group in IGT. There is also evidence that oxygenation for the diet group decreased compared with the meditation and exercise groups for the TSt and compared with the meditation group for the Corsi test. This could be explained by a more economical mode of activity of the whole organism under conditions of resource limitation. At the same time, the increase in oxygenation during problem solving in people who performed physical training is often explained by the general training of the cardiovascular system (Hötting et al., 2012), and for meditators—a conscious focus on brain activity (Miyashiro et al., 2021). We got little meaningful results for the diet group, partially because most of this group did not make it to the end of the study. Due to the low diet group size, only the high-impact results were recorded as significant.

Less expected results were obtained for changes in functional connectivity. When interpreting these results, we aim to be cautious. However, it is important to note that observed changes significantly depend on chosen metric. Additionally, the limitations arise from the fact that many of these metrics are based on correlation. In the current study we observed the decrease in coherence in the M and E groups compared to the C and D groups in a resting state. At the same time, there was an increase in functional connectivity in the meditation group compared with the control group (interhemispheric in the SSt, in the Corsi test on the right side) and compared with the diet group (in the left hemisphere in the IGT) and an increase in functional connectivity in the exercise group in comparison with the control group in the Corsi test. Meanwhile, these results are quite logical and may be accounted for the efficiency of the brain of meditators and the group of sports has increased: lower energy consumption in a resting state and higher synchronization in solving specific problems. The evidence from meditation research is more conclusive. For example, a decrease in functional connectivity during meditation has been shown for all frequency ranges for five different meditation traditions (Lehmann et al., 2012). It is well known that the activity of the default mode network in experienced meditators decreases in comparison with the beginners, with a higher connectivity of the executive network of the brain, according to fMRI data (Brewer et al., 2011).

At the same time, the data on the change in connectivity after several weeks of physical training are less clear-cut. For example, 12 weeks of walking showed an increase in functional connectivity in the PCC/precuneus for the elderly (Chirles et al., 2017). Similarly, 6-week Quadrato motor training in adults resulted in increased limbic and frontal-temporal connectivity in the alpha range with open eyes in a resting state (Lasaponara et al., 2017). At the same time, it was shown that gymnasts have a decrease in functional connectivity in the frontal-parietal and cingulo-opercular networks of attention control in a resting state. According to the authors, this decreased rs-FC might be due to the high intensity and amount of training suggesting a strong degree of automaticity leading to an increased neural efficiency (Dosenbach et al., 2007). Analyzing the studies on the effect of exercise on EEG data presented in the meta-review (Gramkow et al., 2020) showed that the final results are often contradictory, depending on the intervention and method of data processing. Perhaps such a difference in research results for meditation and sports can be explained by the fact that, regardless of the type of meditation, the practitioner often strives to control attention and stop the mind-wandering. While in physical activity the following processes can prevail: an increase in power of the cardiovascular system, muscle growth, the increasing function of attention and thinking for playing sports, learning new movements, and redistributing the body's resources. Another interesting outcome of our results is that for an exercise group at rest, frontal-occipital connectivity decreases across all frequency ranges. Another work (Beaty et al., 2018) shows the correlation between connectivity and creativity. In this article, creative people have higher fronto-occipital connectivity than noncreative people. Hence, it can be assumed that exercise for beginners can negatively affect their creativity. Although, in our work, in contrast to the work of Beaty et al. (2018), EEG was used instead of fMRI. However, it is not always possible to extrapolate trends in functional connectivity obtained for the EEG to fMRI data and vice versa (Plis et al., 2011), since due to different operating frequency ranges, the trends may not comply or even be opposite (Danks & Plis, 2019).

The fasting group demonstrated a significant decrease in leptin blood concentration. The rapid (in 8 weeks) decrease in serum leptin levels during fasting may indicate that leptin release was regulated by factors other than changes in the body fat mass. The lack of leptin changes during fasting, when basal insulin and glucose levels were maintained at basal levels, suggested that insulin and/or glucose might play a role in leptin release regulation (Boden et al., 1996). In the study of intermittent fasting in adults with mild cognitive impairment, subjects exhibited significant increment in superoxide dismutase activity and reduction in body weight, levels of insulin, fasting blood glucose, malondialdehyde, C-reactive protein (CRP), and DNA damage (Ooi et al., 2020). On the other hand, we observed an increase in norepinephrine. Previous studies on neurotransmitter levels in rats showed that fasting regimes caused a significant increase of serotonin and norepinephrine. Additionally, fasting caused a significant decrease in aspartate aminotransferase (AST), urea, and creatinine, alongside a decrease in the weight of the body, liver, and stomach while causing a significant increase in phagocytic activity and phagocytic index (Shawky et al., 2015). The participants of the current study did not demonstrate significant changes in AST and creatinine, which can be connected to a mild diet plan.

In our study, we found a decreasing trend in urea level in all the groups, which can be explained by seasonal changes that were observed previously (Jacobs et al., 2011). Previous research also indicates that high serum uric acid may negatively influence vascular dementia. Contrarily, moderate levels of uric acid may have neuroprotector function (Tana et al., 2018). We assume that the dynamics of serum uric acid levels should be further monitored and possibly be a predictor of cognitive changes in response to daily routine changes. In our case, there was no significant change in epinephrine concentration in the fasting group, which can be found in patients with ketoacidosis (Christensen, 1974).

The participants in the fasting group demonstrated less consistency in their fatigue perception and sleep duration; there was no strong correlation between fatigue in the days after short sleep periods and sleep quality, as we observed in the other groups. It might be connected to the change in brain neuromediator concentration in blood serum (norepinephrine and serotonin). We assume that norepinephrine and serotonin serum levels can be considered as markers of human performance based on the current finding, and the combination of elevated levels of norepinephrine and decreased level of serotonin may lead to increased work productivity. Another reason for less subjective fatigue in participants might be connected to increased mitochondrial activity, which is observed during intermittent fasting (Lettieri-Barbato et al., 2018). The current finding also provides evidence for mitochondrial influence on mood and cognition (Picard & McEwen, 2014).

We found a significant increase in zinc blood serum concentration in the meditation group. A number of cross-sectional studies have investigated the association between physical activity and zinc status, while the obtained results remain contradictory. Some studies showed lower serum zinc concentration in athletes (Arikan et al., 2008), while other studies report no significant differences in zinc status between athletes and controls (Crespo et al., 1995; Nuviala et al., 1999). Still, there was no evidence reported on the influence of meditation and breathing techniques on zinc blood levels previously. The lack of conformity in the results may be driven by factors other than physical activity levels, for example, differences in dietary habits between the populations. In previous studies there are some evidence that during physical exercise the increase in plasma zinc levels might be the result of muscle leakage of zinc into the extracellular fluid following muscle damage (Noakes, 1987). Also, physical stress produced by exercise involves several neuroendocrine molecules that can interact with the metabolism (Sakata et al., 1991).

In the current study, we found a decrease of the creatinine's level in the meditation group. It is consistent with the previous results on the effect of yoga on creatinine blood level. Patients with chronic kidney disease, undergoing a yoga-training regime along with conventional treatment showed a significant reduction in blood urea and serum creatinine values over a period of 6 months. This can be attributed to the significantly beneficial impact of yoga on renal functions (Pandey et al., 2017). Our work demonstrates the positive effect that short meditations produce on creatinine levels.

Breathing techniques that were used in the daily meditation practices in our study stretch the lung tissue and produce inhibitory signals from the action of slowly adapting receptors and hyperpolarizing currents. These inhibitory signals coming from cardiorespiratory regions might influence the functions of the autonomic nervous system and are associated with resultant conditions characterized by reduced metabolism and parasympathetic dominance (Balaji et al., 2012). Previous studies confirmed that 30 min of daily yoga practice for 4 months showed a significant reduction in oxidative stress (malondialdehyde, protein oxidation, and phospholipase A2 activity) and an increase in antioxidant activity (superoxide dismutase and catalase activities) in patients with chronic kidney disease who were experiencing hemodialysis treatment (Gordon et al., 2013).

Daily observations of HRV levels in the meditation group demonstrated improvement in HRV parameters right after meditation. There was also a significant decrease in HRV levels in comparison to the other groups at the end of the 8th week of the study. However, we did not find any changes in neuromediator blood serum concentration. The correlation between subjective perception of fatigue and sleep duration remained unchanged throughout the study, while some of the recent studies on hemodialysis patients demonstrated that 12-week yoga intervention has proven to alter fatigue levels (Yurtkuran et al., 2007). The same study reported a significant reduction in creatinine, blood urea, alkaline phosphatase, and cholesterol along with significant improvement in erythrocyte and hematocrit count, which is consistent with our observations of creatinine and uric acid blood levels.

Changes in the concentration of uric acid and creatinine were registered in exercise groups which is consistent with previous studies (El Abed et al., 2011; Groussard et al., 2003; Hammouda et al., 2012). These findings are also consistent with previous observations showing that short aerobic exercise increases pro-oxidants more than anaerobic exercise (El Abed et al., 2019). We found that physical exercise led to better attention and reaction according to the daily tests and comparison of pre- and poststudy cognitive test results. It has been previously highlighted that physical exercise is related to improvement in reaction time (van de Water et al., 2017). Previous research also demonstrated that physical activity and exercise could support the development of cognitive functioning and specifically attention (Kao et al., 2017). For this reason, it could be considered that the practice of physical exercise and the development of physical condition could have an impact on reaction time, whether directly, through training of the capacity to respond to a given stimulus, or indirectly, through the impact it would have on cognitive functioning (Gentier et al., 2013).

The amount of daily physical activity has been related to reaction time. The participants who had more hours (more than 60 min a day) of physical activity showed a faster reaction. These results are congruent with previous research that had pointed out such associations (Okubo et al., 2017; Reigal et al., 2019). The significant differences in cognitive test results emphasize the importance of regular physical training for healthy adults. There was no correlation between fatigue and duration of exercise. While physical exercise therapy has been shown to increase HRV in healthy individuals (Dixon et al., 1992; Furlan et al., 1993; Pichot et al., 2005), we did not observe a significant long-term effect of exercise on HRV levels.

## Conclusion

The significant results of the pilot study show specific correlations between changes in cognitive functions, patterns of brain activity, and physiological parameters with the type of activity. Specifically, physical activity may have a positive effect on cognitive functions, especially in tasks related to attention and reaction time. In addition, the longer the exercise session, the faster the reaction time. However, physical exercise can have a negative effect on creativity in those with the condition. Meditation can be considered an effective way to improve executive functions. Although exercise and meditation have more immediate and direct positive effects, diet may have long-term benefits for brain performance.

Insight into the various influences of these physical and mental practices may help tailor interventions aimed at improving physiological and cognitive well-being. However, to make more accurate conclusions, it is necessary to conduct a series of studies on large samples, where different ages, sex, and types of activity will be widely represented, and also separate close-up studies for each area of activity, taking into account various mechanisms of influence on a person.

## Author Declaration

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## Appendix A

**Table A1**

*Significant Differences in Changes for Different Interventions for the Stop Signal Test. SD – Standard Deviation*

| Test Results (Inhibitory Latency, ms) ± *SD* | | | | | |
|---|---|---|---|---|---|
| Meditation > Control | Meditation | Control | *p*-value | power | effect |
| | 12.97 ± 41.99 | −43.78 ± 57.39 | .02 | 0.76* | 1.11 |
| Diet > Control | Diet | Control | *p*-value | power | effect |
| | 9.90 ± 49.07 | −43.78 ± 57.39 | .02 | 0.61* | 1.01 |
| Sport > Control | Sport | Control | *p*-value | power | effect |
| | 16.38 ± 49.07 | −43.78 ± 57.39 | .02 | 0.81 | 1.13 |
| Functional Connectivity (Coherence) ± *SD* | | | | | |
| Meditation > Sport | Meditation | Sport | *p*-value | power | effect |
| Interhemispheric theta | 0.125 ± 0.150 | −0.055 ± 0.066 | .03 | 0.76* | 1.55 |
| C3 P3 theta | 0.173 ± 0.155 | −0.096 ± 0.104 | .01 | 0.93 | 2.04 |
| Interhemispheric alpha | 0.106 ± 0.118 | −0.066 ± 0.064 | .02 | 0.87 | 1.81 |
| C4 C3 alpha | 0.193 ± 0.137 | −0.159 ± 0.160 | .02 | 0.97 | 2.36 |
| C3 P3 beta1 | 0.161 ± 0.180 | −0.185 ± 0.118 | .03 | 0.96 | 2.27 |
| Interhemispheric all rhythms | 0.089 ± 0.127 | −0.079 ± 0.060 | .05 | 0.82 | 1.69 |
| C4 C3 all rhythms | 0.149 ± 0.170 | −0.144 ± 0.119 | .02 | 0.92 | 2.00 |
| Meditation > Control | Meditation | Control | *p*-value | power | effect |
| Interhemispheric theta | 0.125 ± 0.150 | −0.053 ± 0.082 | .03 | 0.73* | 1.47 |
| C3 P3 theta | 0.173 ± 0.155 | −0.046 ± 0.121 | .01 | 0.79* | 1.57 |
| Interhemispheric alpha | 0.106 ± 0.118 | −0.066 ± 0.077 | .02 | 0.84 | 1.73 |
| C4 C3 alpha | 0.193 ± 0.137 | −0.099 ± 0.133 | .02 | 0.95 | 2.16 |
| Interhemispheric all rhythms | 0.089 ± 0.127 | −0.089 ± 0.103 | .05 | 0.76* | 1.54 |
| C4 C3 all rhythms | 0.149 ± 0.170 | −0.112 ± 0.157 | .02 | 0.78* | 1.60 |

* = Power size below 0.8.

**Table A2**

*Significant Differences in Changes for Different Interventions for the Task Switching Test. SD – Standard Deviation*

| | | | | | |
|---|---|---|---|---|---|
| Test Results (Switching Cost, ms) ± *SD* | | | | | |
| Meditation > Diet | Meditation | Diet | *p*-value | power | effect |
| | 255.22 ± 317.20 | −72.89 ± 320.90 | .03 | 0.71* | 1.03 |
| Meditation > Sport | Meditation | Sport | *p*-value | power | effect |
| | 255.22 ± 317.20 | −106.55 ± 386.17 | .03 | 0.85 | 1.03 |
| FNIRS (ΔTSI) ± *SD* | | | | | |
| Meditation > Diet | Meditation | Diet | *p*-value | power | effect |
| | 0.38 ± 1.60 | −2.48 ± 2.50 | .04 | 0.84 | 1.36 |
| Sport > Diet | Sport | Diet | *p*-value | power | effect |
| | 0.22 ± 2.46 | −2.48 ± 2.50 | .04 | 0.68 | 1.10 |
| Functional Connectivity (Coherence) ± *SD* | | | | | |
| Meditation > Sport | Meditation | Sport | *p*-value | power | effect |
| C3 O1 theta | 0.064 ± 0.108 | −0.140 ± 0.053 | .02 | 0.99 | 2.40 |
| C4 C3 theta | 0.128 ± 0.207 | −0.206 ± 0.152 | .04 | 0.94 | 1.83 |
| C4 O1 beta2 | 0.055 ± 0.063 | −0.078 ± 0.066 | .04 | 0.97 | 2.06 |
| C4 C3 beta2 | 0.089 ± 0.156 | −0.178 ± 0.066 | .04 | 0.99 | 2.23 |
| F4 C3 all rhythms | 0.058 ± 0.069 | −0.138 ± 0.078 | .05 | 0.99 | 2.66 |
| Control > Sport | Sport | Control | *p*-value | power | effect |
| C3 O1 theta | −0.140 ± 0.054 | 0.009 ± 0.101 | .02 | 0.96 | 1.84 |
| C4 O1 beta2 | −0.078 ± 0.066 | 0.023 ± 0.063 | .04 | 0.89 | 1.56 |
| F4 C3 all rhythms | −0.138 ± 0.078 | 0.041 ± 0.122 | .05 | 0.94 | 1.75 |

**Table A3**
*Significant Differences in Changes for Different Interventions for the Corsi Test. SD – Standard Deviation*

| FNIRS (ΔTSI) ± *SD* | | | | | |
|---|---|---|---|---|---|
| Meditation > Diet | Meditation | Diet | *p*-value | power | effect |
| | 1.39 ± 1.53 | −1.98 ± 2.05 | .03 | 0.95 | 1.86 |
| Relative Power Spectrum Changes ± *SD* | | | | | |
| Meditation > Sport | Meditation | Sport | *p*-value | power | effect |
| Left hemisphere beta 1 | 0.028 ± 0.027 | −0.070 ± 0.053 | .04 | 0.99 | 2.33 |
| Meditation < Sport | Meditation | Sport | *p*-value | power | effect |
| Frontal beta2 | −0.050 ± 0.020 | 0.041 ± 0.058 | .05 | 0.99 | 2.47 |
| Meditation < Control | Meditation | Control | *p*-value | power | effect |
| Average beta2 | −0.036 ± 0.026 | 0.071 ± 0.048 | .02 | 0.99 | 2.77 |
| Frontal beta2 | −0.050 ± 0.020 | 0.125 ± 0.101 | .05 | 0.99 | 2.40 |
| Sport < Control | Sport | Control | *p*-value | power | effect |
| Average beta2 | 0.012 ± 0.037 | 0.071 ± 0.048 | .02 | 0.78* | 1.38 |
| Functional Connectivity (Coherence) ± *SD* | | | | | |
| Meditation > Control | Meditation | Control | *p*-value | power | effect |
| P4 C4 theta | 0.147 ± 0.187 | −0.130 ± 0.122 | .03 | 0.94 | 1.75 |
| P4 C4 alpha | 0.152 ± 0.187 | −0.128 ± 0.132 | .02 | 0.94 | 1.74 |
| Sport > Control | Sport | Control | *p*-value | power | effect |
| P4 C4 theta | 0.082 ± 0.078 | −0.130 ± 0.122 | .03 | 0.97 | 2.07 |
| P4 C4 alpha | 0.104 ± 0.051 | −0.128 ± 0.132 | .02 | 0.99 | 2.32 |

**Table A4**
*Significant Differences in Changes for Different Interventions for the Iowa Gambling Test. SD – Standard Deviation.*

| FNIRS (ΔTSI) ± *SD* | | | | | |
|---|---|---|---|---|---|
| Control > Diet | Control | Diet | *p*-value | power | effect |
| | 1.29 ± 3.42 | −2.49 ± 2.93 | .04 | 0.61* | 1.19 |
| Functional Connectivity (Coherence) ± *SD* | | | | | |
| Meditation > Diet | Meditation | Diet | *p*-value | power | effect |
| C3 P3 beta1 | 0.093 ± 0.104 | −0.160 ± 0.136 | .03 | 0.60* | 2.09 |
| O2 P3 gamma | 0.086 ± 0.091 | −0.100 ± 0.061 | .03 | 0.99 | 2.40 |
| Control > Diet | Diet | Control | *p*-value | power | effect |
| O2 P3 gamma | −0.100 ± 0.061 | 0.044 ± 0.068 | .03 | 0.93 | 2.22 |

* = Power size below 0.8.

**Table A5**

*Open Eyes Resting State. Significant Differences in Changes for Different Interventions for the Resting State With Open Eyes. SD – Standard Deviation*

| Functional Connectivity (Coherence) ± *SD* | | | | | |
|---|---|---|---|---|---|
| Meditation < Diet | Meditation | Diet | *p*-value | power | effect |
| Sagittal theta | −0.055 ± 0.116 | 0.136 ± 0.189 | .002 | 0.66 | 1.21 |
| Sagittal alpha | −0.023 ± 0.136 | 0.182 ± 0.175 | .004 | 0.71 | 1.31 |
| Meditation < Control | Meditation | Control | *p*-value | power | effect |
| Sagittal theta | −0.055 ± 0.116 | 0.168 ± 0.111 | .002 | 0.97 | 1.96 |
| Left hemisphere theta | 0.0001 ± 0.117 | 0.130 ± 0.082 | .003 | 0.74* | 1.29 |
| Sport < Diet | Sport | Diet | *p*-value | power | effect |
| Sagittal theta | −0.087 ± 0.066 | 0.136 ± 0.189 | .002 | 0.84 | 1.58 |
| Interhemispheric theta | −0.063 ± 0.062 | 0.098 ± 0.060 | .020 | 0.99 | 2.63 |
| Left hemisphere theta | −0.092 ± 0.051 | 0.105 ± 0.108 | .003 | 0.98 | 2.33 |
| Sagittal alpha | −0.093 ± 0.066 | 0.182 ± 0.175 | .004 | 0.97 | 2.08 |
| Average alpha | −0.063 ± 0.064 | 0.129 ± 0.142 | .040 | 0.90 | 1.74 |
| Left hemisphere alpha | −0.098 ± 0.093 | 0.135 ± 0.134 | .040 | 0.96 | 2.02 |
| Interhemispheric beta2 | −0.086 ± 0.064 | 0.090 ± 0.121 | .020 | 0.92 | 1.81 |
| Sport < Control | Sport | Control | *p*-value | power | effect |
| Average theta | −0.055 ± 0.040 | 0.111 ± 0.079 | .020 | 0.99 | 2.65 |
| Sagittal theta | −0.087 ± 0.066 | 0.168 ± 0.111 | .002 | 0.99 | 2.79 |
| Interhemispheric theta | −0.063 ± 0.062 | 0.096 ± 0.086 | .020 | 0.98 | 2.12 |
| Left hemisphere theta | −0.092 ± 0.051 | 0.130 ± 0.082 | .003 | 0.99 | 3.25 |
| Sagittal alpha | −0.093 ± 0.066 | 0.144 ± 0.093 | .004 | 0.99 | 2.93 |
| Left hemisphere beta1 | −0.055 ± 0.089 | 0.098 ± 0.072 | .040 | 0.97 | 1.89 |
| Interhemispheric beta2 | −0.086 ± 0.064 | 0.100 ± 0.120 | .020 | 0.97 | 1.93 |

* = Power size below 0.8.

## Appendix B

The Exercise group alternated between the first type of program (on the first training day) and the second type (on the second training day) throughout the entire experimental period.

### Program 1 (Main Section):

1. Latissimus dorsi (back muscles)
    - Wide-grip lat pulldown to the chest
    - Wide-grip lat pulldown behind the neck
    - Narrow reverse-grip lat pulldown with a shortened range of motion
    - Horizontal row on a machine

Series: Three sets of 30–40 s each; 30-s rest between sets.

2. Pectoral muscles (chest muscles)
    - Wide-grip push-ups
    - Barbell press on a bench or machine
    - Dumbbell Flyes

Series: Three sets of 30–40 s each; 30-s rest between sets.

3. Abdominal muscles (abs)
    - Torso curls with hands in front (slight elevation, shoulders not touching the floor)
    - Leg raises while lying on the back (45–80 degrees at the hip joint)
    - Bent leg raises in a combined machine (short range of motion)
    - Vertical leg raises while lying on the back, lifting the glutes off the floor: additional weights and machines can be used.
    - Curls with a slight twist and side leg raises
    - Torso curls while lying, knees bent and turned to one side (touching the floor)
    - Torso curls while lying, knees bent and turned to one side (touching the floor)

Series: Three sets of 30–40 s each; 30-s rest between sets.

4. Leg muscles (gluteal muscles)
    - Leg press (feet positioned high on the platform)
    - Extensions on an inclined bench
    - Squats in a Smith machine

Series: Three sets of 30–40 s each; 30-s rest between sets.

*Two sets in total.

### Program 2 (Main Section):

1. Muscles of the front thigh
    - Forward lunges
    - Leg extensions on a machine
    - Knee raises while standing on one leg (using weights or resistance bands)
    - Leg raises (straight or slightly bent) while lying down (using weights or resistance bands)
    - Squats
    - Leg press
    - Half-lunge squats: 30–40 s per leg
    - Leg curls on a machine
    - Hip extensions (backward) while standing or lying down (using weights, resistance bands, crossover machine, or body weight)
    - Knee curls while standing or lying down (using weights, resistance bands, or body weight)
    - Pelvic paises with one leg support

Series: Three sets of 30–40 s; 30-s rest between sets.

2. Muscles of the back thigh
    - Leg curls on a machine
    - Hip extensions (backward) while standing or lying down (using weights, resistance bands, crossover machine, or body weight)
    - Knee curls while standing or lying down (using weights, resistance bands, or body weight)
    - Pelvic paises with one leg support

Series: Three sets of 30–40 s; 30-s rest between sets.

3. Muscles of the back calf
    - Calf raises with body weight or external weights (barbell, Smith machine)
    - Seated calf raises with external weights (barbell, dumbbells, etc.) or on a machine
    - Foot flexions on a machine

Series: Three sets of 30–40 s; 30-s rest between sets.

4. Abdominal muscles
    - Torso curls with hands in front (slight elevation, shoulders not touching the floor)
    - Leg raises while lying on the back (45–80 degrees at the hip joint)
    - Bent leg raises in a combined machine (short range of motion)
    - Vertical leg raises while lying on the back, lifting the glutes off the floor: additional weights and machines can be used.
    - Curls with a slight twist and side leg raises
    - Torso curls while lying, knees bent and turned to one side (touching the floor)
    - Torso curls while lying, knees bent and turned to one side (touching the floor)

Series: Three sets of 30–40 s; 30-s rest between sets.

*Two sets in total.