

NEUROLOGY AND NEUROSURGERY

PSYCHOPHYSIOLOGICAL CHARACTERISTICS OF COGNITIVE FUNCTIONS IN MIDDLE-AGED AND OLDER ADULTS AND THE EFFECT OF PHYTOCONSTITUENTS WITH NOOTROPIC PROPERTIES ON THEM

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ABSTRACT

Background. Maintaining cognitive health and preventing dementia are priorities in modern medicine and science. Nootropics play an important role in neuroprotection. Multicomponent herbal remedies containing medicinal plant extracts hold promise as phytopharmacological regulatory systems for maintaining and restoring cognitive health.

Aim. To analyze the psychophysiological characteristics of cognitive functions in middle-aged and older adults and to assess the effect of a phytoconstituent with nootropic properties on these characteristics.

Materials and methods. Before and after a course of treatment with the phytoconstituent, participants underwent a comprehensive examination that included electrocardiography with heart rate variability assessment; evaluation of short-term and long-term memory using the "10-Word Memorization" test by A.R. Luria; and assessment of logical thinking using the "Complex Analogies" test.

Results. The study identified two groups of participants: those with moderate and those with high levels of working memory and logical thinking. Group 1 was characterized by low parasympathetic nervous system markers and reduced heart rate variability. Group 2 demonstrated higher heart rate variability and elevated parasympathetic markers. After administration of the phytoconstituent, parasympathetic activity markers (RMSSD, HFmc², HF%) increased in Cluster 1 and decreased in Cluster 2. Following the course of the phytoconstituent, Group 1 exhibited a more pronounced improvement in memory indices and logical reasoning abilities.

Conclusion. An association was found between high levels of working memory and logical thinking and a predominance of parasympathetic influences on heart rhythm. Administration of the herbal preparation with nootropic properties resulted in improved cognitive function and a balanced autonomic nervous system.

Key words: cognitive functions, nootropic agents, heart rate variability, autonomic nervous system

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ПСИХОФИЗИОЛОГИЧЕСКИЕ ОСОБЕННОСТИ КОГНИТИВНЫХ ФУНКЦИЙ У ПРЕДСТАВИТЕЛЕЙ ЗРЕЛОГО И ПОЖИЛОГО ВОЗРАСТА И ВЛИЯНИЕ НА НИХ ФИТОКОМПОЗИЦИИ С НООТРОПНЫМИ СВОЙСТВАМИ

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РЕЗЮМЕ

Актуальность. Сохранение когнитивного здоровья и профилактика деменции – приоритетные задачи современной медицины и науки. Ноотропы занимают важное место в нейропротекции. Многокомпонентные фитосредства с экстрактами лекарственных растений перспективны как фитотерапевтические регуляторные системы для поддержания и восстановления когнитивного здоровья.

Цель исследования. Провести анализ психофизиологических особенностей когнитивных функций у представителей зрелого и пожилого возраста и оценить влияние на них фитокомпозиции (ФК) с ноотропными свойствами.

Материалы и методы. До и после курсового приема фитокомпозиции испытуемым проводили комплексное обследование, включающее электрокардиографию с оценкой вариабельности ритма сердца, оценку функции кратковременной и долговременной памяти с помощью теста «Заучивание 10 слов» А.Р. Лурия, логическое мышление оценивали с помощью теста «Сложные аналогии».

Результаты. Исследование выявило две группы испытуемых: со средним и высоким уровнем развития рабочей памяти и логического мышления. Первая группа характеризовалась низкими значениями маркеров парасимпатической нервной системы и низкой вариабельностью ритма сердца. Вторая группа отличалась высоким уровнем вариабельности сердечного ритма, высокими значениями маркеров парасимпатической нервной системы. После приема ФК величины маркеров парасимпатической активности RMSSD, HFms² и HF% возрастали у членов первого кластера и снижались у членов второго кластера. После приема ФК в первой группе в большей степени улучшались показатели памяти и способности к логическому мышлению.

Заключение. Показана связь между высокими показателями рабочей памяти и логического мышления и преобладанием парасимпатических влияний на ритм сердца. Прием фитокомпозиции с ноотропными свойствами вызывал улучшение когнитивных функций и выравнивание баланса вегетативной нервной системы.

Ключевые слова: когнитивные функции, ноотропные средства, вариабельность ритма сердца, автономная нервная система

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INTRODUCTION

A review of the literature revealed a limited number of studies comprehensively investigating the relationships between cognitive functions and autonomic regulatory mechanisms of cardiac activity, particularly in middle-aged and older adults [1].

Maintaining cognitive health and preventing dementia are priorities in modern medicine and science [2]. Nootropics play an important role in neuroprotection and can improve memory, performance, and adaptive capabilities of the brain in older adults [3, 4]. Epidemiological data indicate the need for the development of affordable domestic nootropics. Multicomponent herbal preparations containing medicinal plant extracts have the potential to be used as phytopharmacological regulatory systems for maintaining and restoring cognitive health [5, 6].

In 2023, a research team from the Institute of Biomedicine at Altai State University, as part of the project "Development of functional products for restoring body functions during age-related changes and evaluation of their effectiveness" under the Priority-2030 program, developed a phytoconstituents (PC) with nootropic properties. Identifying the mechanisms by which this PC influences human cognitive functions is of current relevance.

AIM

To analyze the psychophysiological characteristics of cognitive functions in middle-aged and older adults and to assess the effect of a phytoconstituents with nootropic properties on these characteristics.

MATERIALS AND METHODS

Study Population

The group receiving the PC ($n = 35$) consisted of conditionally healthy volunteers over 45 years of age, who were recruited from various occupations. A total of 35 women aged 45–65 years (mean age 52.3 ± 0.94 years) were examined. The sample size was determined based on the small sample criterion (sample size may not exceed 30 units plus 25 % to account for potential outliers).

All participants provided informed consent prior to participating in the study. Inclusion criteria: voluntary informed consent. Exclusion criteria: chronic diseases, hypertension, blood clotting disorders, alcohol abuse, regular smoking, hypersensitivity to PC components, recurrent gastrointestinal problems, and blood pressure above 130/80 mmHg.

Psychophysiological Research Methods

Before and after the course of PC administration, participants underwent a comprehensive examination that included:

- electrocardiography with the assessment of heart rate variability (HRV) using a Poly-Spectr-8/EX device (Ivanovo, Russian Federation);
- assessment of short-term and long-term memory using the "10-Word Memorization" test developed by A.R. Luria;
- assessment of logical thinking through the "Complex Analogies" test developed by E.A. Korobkova, which evaluates logical reasoning based on the ability to find logical connections between 20 word pairs (classification, antonyms, cause-effect, synonyms, structural connections, group membership), using an online testing service [7].

Pharmacological Substances

The PC included components with significant nootropic, adaptogenic, antioxidant, and antihypoxic properties: astragalus membranaceus extract (20 mg), finely ground boswellia serrata resin (20 mg), Hericium erinaceus fruiting bodies (159 mg) – to stimulate cognitive functions, Ginkgo biloba extract (20 mg) and polyphenols (5 mg) – to improve blood supply, as well as a vitamin complex (vitamins A, C, D, E, K, group B, and vitamin D3). Volunteers were administered one PC capsule twice daily for a period of two weeks.

Ethical Approval

The study was approved by the local ethics committee of Altai State University (Protocol No. 9 dated April 5, 2024).

Statistical Analysis

Statistical data processing was performed using the SPSS 21.0 software package. To check for the normality of the distribution, the Shapiro – Wilk test was employed (significance level $p > 0.05$). For quantitative data that did not follow a normal distribution, the median (Me) and interquartile range ($Q_{25} - Q_{75}$) were used. The non-parametric Kruskal – Wallis test was used for intergroup comparisons. For normally distributed data, quantitative variables were presented as mean (M) $\pm$ standard error (SE). For intergroup comparisons in cases of normally distributed data, the parametric Student's t -test for independent samples was employed. The Wilcoxon test for paired samples was used to evaluate dynamic changes. Differences were considered statistically significant at $p < 0.05$. Cluster analysis was used to form groups with similar characteristics.

RESULTS

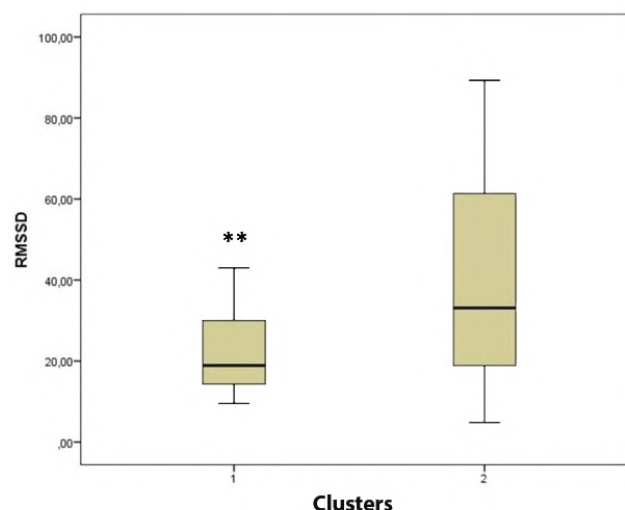
Cluster analysis identified two groups with shared characteristics (Cluster 1, $n = 21$; Cluster 2, $n = 14$). There was no significant difference in age between the clusters (Cluster 1: 51.8 ± 1.25 years; Cluster 2: 52.9 ± 1.47 years; $p = 0.550$). A comparative analysis revealed statistically significant differences in several psychophysiological parameters between the study groups. Using psychophysiological measures, statistically significant intergroup differences were observed in first recall (Cluster 1: 6.3 ± 0.09 ; Cluster 2: 8.8 ± 0.17 ; $p < 0.001$), second recall

(Cluster 1: 8.5 ± 0.13 ; Cluster 2: 9.1 ± 0.12 ; $p < 0.001$), delayed recall (Cluster 1: 8.8 ± 0.16 ; Cluster 2: 10.0 ± 0.03 ; $p < 0.001$), and recall after 24 hours (Cluster 1: 8.8 ± 0.16 ; Cluster 2: 9.6 ± 0.08 ; $p < 0.001$). Analysis of the results from the “Complex Analogies” test revealed that participants in Cluster 2 (9.2 ± 0.52 , $p = 0.046$) demonstrated a significantly greater capacity for establishing logical connections between pairs of words compared to those in Cluster 1 (7.1 ± 0.61), i.e., subjects in Cluster 2 exhibited a higher level of cognitive functioning.

Statistically significant differences were also observed between the study groups in terms of heart rate variability parameters. To assess parasympathetic regulation, the following HRV markers were used [8]: the root mean square of successive RR interval differences (RMSSD) (Fig. 1), as well as the absolute and relative high-frequency power (HF) (Fig. 2). These parameters were significantly lower in subjects of Cluster 1, indicating reduced activity of the parasympathetic division of the autonomic nervous system.

After administration of the PC, parasympathetic activity markers increased in Cluster 1 and decreased approximately 2-fold in Cluster 2. Specifically: In Cluster 1, RMSSD increased by 50 % [before PC: Me 20.0, Q25–75 11.0–43.0; after PC: Me 30.0, Q25–75 16.0–64.0; $p = 0.008$]; HF (ms^2) increased 3-fold [before PC: Me 125.0, Q25–75 25.0–450.0; after PC: Me 375.0, Q25–75 75.0–1350.0; $p = 0.008$]; HF% increased by 50 % [before PC: Me 16.0, Q25–75 8.0–46.0; after PC: Me 24.0, Q25–75 8.0–69.0; $p = 0.008$]. In Cluster 2, RMSSD decreased approximately 2-fold [before PC: Me 42.0, Q25–75

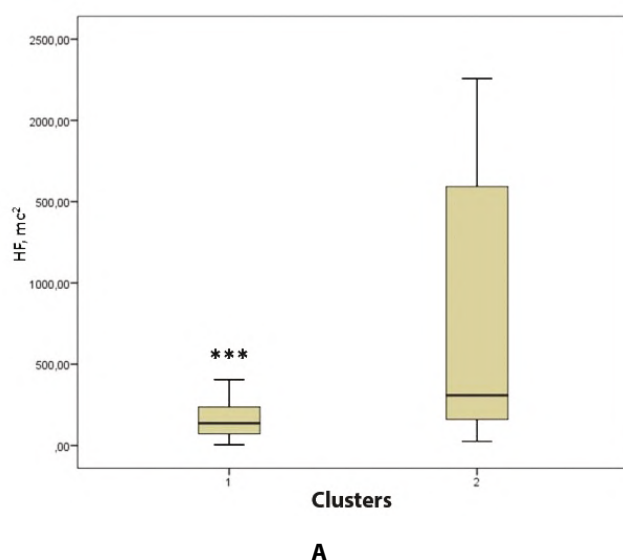
11.0–89.0; after PC: Me 21.0, Q25–75 8.0–45.0; $p = 0.008$]; HF (ms^2) decreased approximately 2-fold [before PC: Me 375.0, Q25–75 30.0–2250.0; after PC: Me 187.0, Q25–75 15.0–1125.0; $p = 0.008$]; HF% decreased by 50 % [before



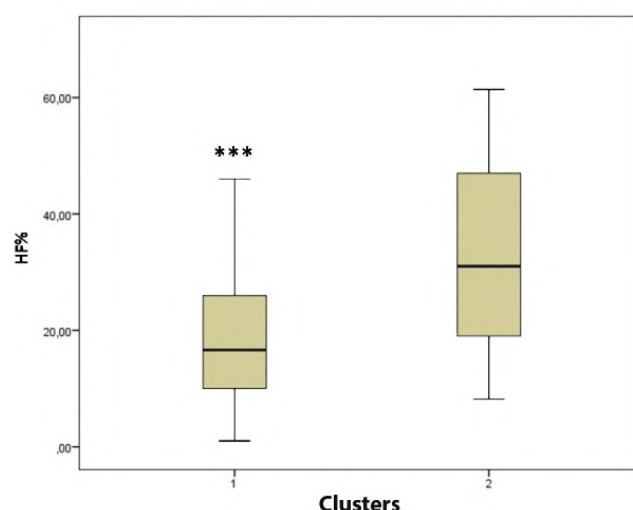
Note. Cluster 1 – individuals with a moderate level of working memory and logical thinking; Cluster 2 – individuals with a high level of working memory and logical thinking; Significant differences between groups: ** – $p < 0.01$.

FIG. 1.

Time-domain heart rate variability parameters (RMSSD) (data are presented as medians and interquartile ranges (Me, Q_{25} – Q_{75}))



A



B

Note. Clusters are the same as in Fig. 1. Significant differences between groups: *** – $p < 0.001$.

FIG. 2.

High-frequency spectral parameters of heart rate variability: A – HF (ms^2) and B – HF (%) (data are presented as medians and interquartile ranges (Me, Q_{25} – Q_{75}))

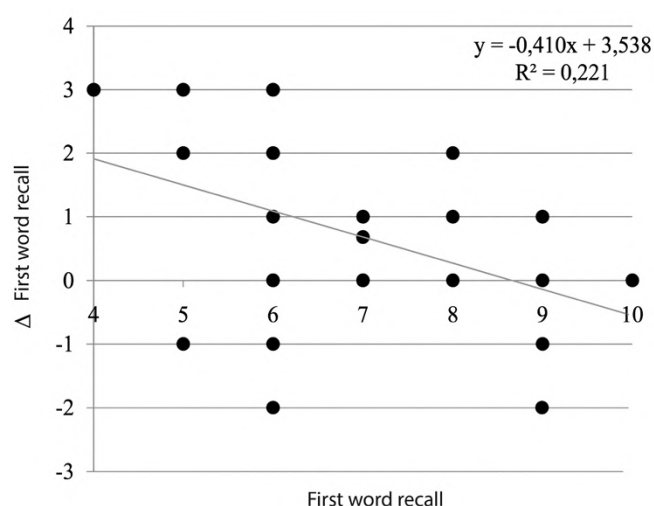


FIG. 3. Correlation between the first recall delta and the number of words recalled. The figure shows the regression equation

PC: Me 31.0, Q25–75 8.0–61.0; after PC: Me 15.5, Q25–75 5.0–30.0; $p = 0.008$].

Administration of the PC led to a statistically significant increase in memory performance. First recall in Cluster 1 increased by 8 % (from 6.3 ± 0.09 to 6.8 ± 0.17 , $p < 0.001$), while in Cluster 2 it increased by 1 % (from 8.8 ± 0.17 to 8.9 ± 0.17 , $p = 0.317$). Delayed recall in Cluster 1 increased by 7 % (from 8.8 ± 0.16 to 9.4 ± 0.17 , $p < 0.001$) and in Cluster 2 by 2 % (from 10.0 ± 0.03 to 10.0 ± 0.03 , $p = 1.00$). Recall after 24 hours increased by 6 % in Cluster 1 (from 8.8 ± 0.16 to 9.3 ± 0.17 , $p < 0.001$) and by 1 % in Cluster 2 (from 9.6 ± 0.08 to 9.7 ± 0.08 , $p = 0.157$).

Following PC administration, there was a statistically significant increase in scores on the “Complex Analogies” test, reflecting an improvement in logical-analytical abilities. Specifically, a statistically significant improvement was observed compared to baseline, predominantly in subjects from Cluster 1 (by 39 %) and Cluster 2 (by 23 %). For Cluster 1, the mean score increased from 7.1 ± 0.85 to 9.9 ± 0.61 , $p = 0.004$. For Cluster 2, the mean score increased from 9.2 ± 0.52 to 11.3 ± 0.64 , $p = 0.002$.

The effectiveness of the PC is likely to be largely determined by the baseline level of brain function. The most pronounced effect of the preparation was observed among individuals with lower baseline memory performance. Specifically, the delta (difference between pre- and post-PC values) in first word recall was negatively dependent on the baseline number of words recalled (Fig. 3). Correlation analysis revealed a moderate negative correlation between these variables ($r = -0.470$, $p = 0.005$).

Similar results were obtained for the delta values of second recall, delayed recall, and 24-hour recall. This

indicates that the effect of the PC is more pronounced in individuals with more substantially reduced cognitive function at baseline.

DISCUSSION

Comparison of our results with data from other researchers also showed that high heart rate variability is associated with better cognitive characteristics and effective adaptive abilities [1, 9, 10]. The results obtained in the current study confirm data previously reported in a study conducted with officers of the Royal Norwegian Navy [9].

It is known that reduced heart rate variability may be associated with decreased cognitive efficiency, particularly reduced working memory and attention function, as well as prolonged sensorimotor reaction time [11]. Moreover, low HRV values are considered a potential predictor of an increased risk of cardiovascular diseases, cognitive dysfunction, and neurodegenerative processes, especially in older adults [12]. Our results indicate the importance of parasympathetic regulation in ensuring cognitive performance efficiency.

A comparison of the results from the phytoconstituents study with data on Ginkgo biloba extract [13] revealed a similarity in the findings: in older women and individuals with initially reduced cognitive abilities, the impact on cognitive processes was more significant.

Based on the study conducted, it can be concluded that the phytoconstituents have a beneficial effect on cognitive functions, including memory and thought processes. Given the increasing interest in plant-based agents with neuroprotective properties, the development of novel phytopreparations is becoming highly relevant. The creation and implementation of the phytoconstituents may contribute to expanding the domestic range of agents with proven efficacy in the field of cognitive neuroprotection.

CONCLUSION

The study identified two groups of participants: those with moderate and those with high levels of working memory and logical thinking. The first group had reduced parameters of the parasympathetic nervous system activity. The second group, in contrast, demonstrated increased values of the parameters reflecting the function of the parasympathetic system. After administration of the phytoconstituents, the participants in the first group exhibited a more significant improvement in cognitive functions, accompanied by a shift in autonomic nervous system balance.

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Conflicts of interest

The authors declare no conflicts of interest.

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