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Gender characteristics of cognitive and emotional status, cerebral blood flow at different levels of academic stress

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Abstract. ***Introduction.*** A progressive trend in the field of healthcare and education is a personalized approach, which determines the urgency of searching for individual risk factors for the development of asthenic syndrome in young people in order to create an optimized educational trajectory and measures to prevent asthenic syndrome. ***The aim of the study.*** To evaluate the relationship between individual psychophysiological characteristics, variations in cerebral blood flow and risk factors for asthenic syndrome, taking into account gender, and to compare the effectiveness of options for preventing asthenic syndrome. ***Materials and methods.*** The study involved 147 students divided into two groups based on gender. The students were tested in three stages under different conditions of basic workload and stress levels through a specially designed and standardized online questionnaire. The assessment of the personal characteristics of cerebral circulation was carried out using the rheoencephalography technique. Cognitive training games and transcranial micropolarization were used for stimulation. ***Results.*** Men have more pronounced reserves of cognitive functions, they demonstrate a more stable state to the basic level of stress and intellectual load, however, with increasing psychocognitive load, they experience a marked increase in asthenia, which may indicate limited compensatory resources under prolonged exposure to stress factors. Women, on the contrary, have a higher predisposition to asthenic manifestations against the background of a basic level of stress, however, with an increase in the intensity of stress, they demonstrate better adaptation and less variability in their emotional state. ***Conclusions.*** The results of the study indicate that gender differences have an impact on psychophysiological characteristics under different intellectual and stress loads. The data obtained can be used to develop individual educational trajectories, while creating mobile applications to optimize daily routines in order to increase the effectiveness of the educational process and prevent the development of asthenic syndrome.

Keywords: asthenic syndrome, educational process, cognitive functions, compensatory abilities, young people

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Половые особенности когнитивного и эмоционального статуса, мозгового кровотока при разных уровнях академического стресса

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Резюме. ***Введение.*** Прогрессивной тенденцией в сфере здравоохранения и образования является персонифицированный подход, что обусловливает актуальность поиска индивидуальных факторов риска развития астенического синдрома у лиц молодого возраста с целью создания оптимизированной образовательной траектории и мероприятий по профилактике астенического синдрома. ***Цель исследования*** — оценить взаимосвязь индивидуальных психофизиологических особенностей, вариаций мозгового кровотока и факторов риска развития астенического синдрома с учетом половой принадлежности, сравнить эффективность вариантов профилактики астенического синдрома. ***Материалы и методы.*** В исследовании приняли участие 147 студентов, разделенных на две группы по половому признаку. Студенты прошли тестирование, проведенное в три этапа в разных условиях базовой нагрузки и уровня стресса посредством специально разработанного и стандартизированного онлайн-анкетирования. Личностные особенности мозгового кровообращения оценивали с помощью методики реоэнцефалографии. Для стимуляции использовали игры на тренировку когнитивных функций и транскраниальную микрополяризацию. ***Результаты.*** У мужчин отмечены более выраженные резервы когнитивных функций, они демонстрируют более устойчивое состояние к базовому уровню стресса и интеллектуальной нагрузки, однако при возрастании психокогнитивной нагрузки у них наблюдается выраженный рост показателей астении, что может указывать на ограниченные возможности компенсаторных ресурсов при длительном воздействии стресс-факторов. У женщин, напротив, отмечена более высокая предрасположенность к астеническим проявлениям на фоне базового уровня нагрузки, однако при увеличении интенсивности стрессового воздействия они демонстрируют лучшую адаптацию и меньшую вариабельность эмоционального состояния. ***Выводы.*** Результаты исследования свидетельствуют, что гендерные различия влияют на психофизиологические характеристики при различной интеллектуальной и стрессовой нагрузке. Полученные данные могут использоваться при разработке индивидуальных образовательных траекторий, создании мобильных приложений для оптимизации распорядка дня с целью повышения результативности образовательного процесса и профилактики развития астенического синдрома.

Ключевые слова: астенический синдром, образовательный процесс, когнитивные функции, компенсаторные возможности, лица молодого возраста

Источник финансирования. Авторы заявляют об отсутствии внешнего финансирования при проведении исследования.

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INTRODUCTION

Recent years have seen a growing trend across all spheres of life to adopt a personalized approach. The aim is to tailor products and services as closely as possible to people's needs and capabilities [1–4]. Educational policy also emphasizes creating personalized learning paths for each student, taking into account their individual characteristics [2–4]. Knowledge of individual characteristics of cognitive status and emotional balance, as well as variations in cerebral blood flow, can contribute to creating a system of learning that is both highly effective and physiologically sound. This can significantly improve the effectiveness of educational processes and help prevent functional disorders in many organs and systems [1, 5].

One such disorder associated with prolonged or intense psychological and emotional stress is asthenic syndrome [6–8]. This is a borderline condition between health and illness, which clinically manifests as an energy deficit and an inability to maintain functional activity as before (a phenomenon of intolerance to habitual activities) [9–11].

Thus, identifying the interrelationship between risk factors for the asthenic syndrome, indicators of emotional balance, and cognitive status in young adults is relevant from the perspective of creating an individualized educational trajectory [12–14]. The use of an optimal method to address the aforementioned characteristics is equally important for enhancing learning progress in young individuals and preventing asthenic syndrome [15, 16].

AIM

To assess the relationship between individual psychophysiological indicators, cerebral blood flow characteristics, and risk factors for the development of asthenic syndrome, taking gender into account, as well as to compare the effectiveness of methods for preventing asthenia.тении.

MATERIALS AND METHODS

147 third-year students from the Medical Institute of N.P. Ogarev Moscow State University participated in the study; they were divided into two groups based on gender: Group 1 (n=111) consisted of women, and Group 2 (n=36) consisted of men. Both groups were similar in age. The mean age in Group 1 was 19.36±0.13 years, and in Group 2, 18.94±0.13 years. The study included generally healthy participants who reported no complaints. They subjectively considered themselves healthy, did not take medication on a regular basis, and had no chronic somatic diseases according to their medical records. Individuals who had suffered from acute respiratory viral infections within the past month were excluded from the study.

Students underwent testing conducted in three stages under different conditions of baseline workload and stress levels (Stage 1—mid-semester; Stage 2 — during exam period; and Stage 3 — before and after stimulation) using a specially developed and standardized online questionnaire. In the first stage, rheoencephalography (REG) with functional tests (REO-Spectrum, NeuroSoft LLC) was performed for all respondents; a repeat examination was conducted after stimulation in the third stage. The correction methods used included the "Neurostim" transcranial micropolarization stimulator (NeuroSoft LLC) and games designed to train memory and attention. Sixty students were selected for stimulation and divided into four groups based on the intervention method: Group 1 (n_1=15 participants)—dual stimulation (combined use of the transcranial micropolarization technique and neurostimulation games), Group 2 (n_2=15 participants)—control group; Group 3 (n_3=15 participants)—transcranial micropolarization in single mode; Group 4 (n_4=15 participants)—memory and attention training games in single mode.

The online tests "Number Memory" and "Image Memory" were used to determine the level of short-term memory. The "Proofreading Test" (letter version) was used to assess attention characteristics. Indicators of emotional balance were examined using the eight-factor Spielberger Personality Questionnaire. Features of higher nervous activity (HNA) were assessed using Y. Streliau's methodology. Indicators of asthenia were studied using the subjective asthenia assessment scale (MFI-20). Personality-related features of cerebral blood flow were assessed using the REG methodology (REO-spectrum, NeuroSoft LLC) with functional testing. The obtained data were analyzed by medical statistical methods (normality of distribution test, parametric t-test, nonparametric U-test, χ^2 — for assessing the distribution of relative values, r — correlation coefficient; descriptive statistics with the calculation of means and confidence intervals). Differences were considered statistically significant at a probability of a correct prediction of more than 95% ($p < 0.05$).

RESULTS

An analysis of the gender-specific characteristics of the higher nervous activity revealed a predominance of the "Strength of Excitation Processes" and "Mobility of Nervous Processes" in Group 2. The values of

these indicators at the first stage were 62.32±2.49 and 84.15±3.16 conventional units, respectively (p <0.05). During the second stage, which involved a period of intense physical exertion and stress, a predominance of these indicators was also observed in the group of men, with a slight decrease in both groups.

Assessment of short-term memory revealed the following patterns: in both the first and second stages, the indicator was higher in the first group (women) during the first stage, accounting for 85.99±1.41%, and 89.96±1.03% in the second stage. Dynamic changes during the exam period under intense intellectual load were characterized by a slight increase in this indicator in both groups. in Group 1, it amounted to 4.41%, and in Group 2, 4.69% (p <0.05).

The following patterns were identified when evaluating attention measures. The greatest increase during the second stage of the study, specifically during the exam period, was observed across all indicators in Group 2 (men), whereas during the first stage, these indicators were approximately the same in both groups.

Thus, the attention speed score during the first stage of the study in Group 1 (women) was 4.07±0.10 conventional units; in Group 2 (men) — 4.05±0.15 conventional units, and at the second stage — 4.94±0.61 and 10.15±3.75 CUs, respectively. This indicator increased by 17.61% in the women's group and by 60.10% in the men's group (p <0.05). The task accuracy index was calculated using three methods, and in all cases, its values in the first stage of the study were higher in the second group (men). They amounted to 0.73±0.02; 0.69±0.02; and 0.90±0.10 conventional units, respectively. Dynamic changes during the exam period compared to the baseline cognitive load period showed the greatest increase in indicators in the men's group, with minor changes in all three measurements in the women's group. Changes in the men's group were 21.27, 24.50, and 4.85%, respectively (p <0.05).

The assessment of the "Mental Work Capacity" and "Mental Productivity Coefficient" indicators revealed similar patterns. At the first stage, their values were higher in men, amounting to 2.66±0.18 and 875.02±54.44 conventional units, respectively. During the exam period, the maximum increase was also observed in this group (66.16 and 7.41%), whereas women showed the smallest increase (p < 0.05).

When assessing the indicators "Attention Concentration" and "Sustained Attention," the highest values were found in women — 67.36±1.57 and 146.63±18.05 conventional units, respectively. However, in the second stage of the study, a slight decrease in these indicators was observed in the group of women and a significant increase in the group of men (10.63 and 22.79%, respectively; p <0.05).

An analysis of the "Visual Memory Capacity" and "Information Processing Speed" measures demonstrated that during the first stage, under a baseline load, their values were approximately the same in both groups: Group 1 (women) — 724.15±13.76 and 2.2±0.05 conventional units; Group 2 (men) — 725.31±25.21 and 2.25±0.08 conventional units. During the second stage of the study, which took place during the exam period, Group 2 showed an increase in these indicators by 16.12 and 48.04%, while Group 1 showed a slight decrease (p <0.05). The dynamics of some indicators are shown in Fig. 1.

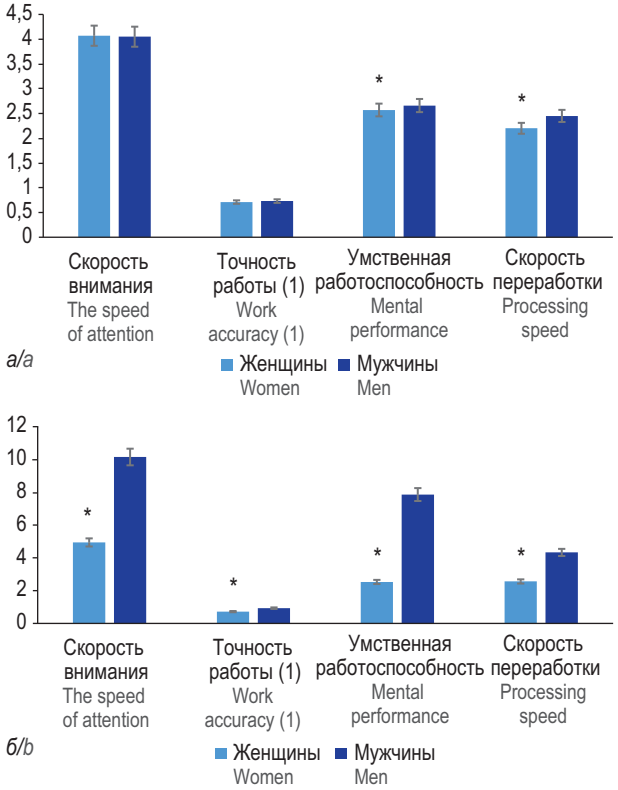


Fig. 1. **Sexual characteristics and dynamic changes in some indicators of attention in young people: a — attention indicators at the 1st stage of the study; b — attention indicators at the 2nd stage of the study. * — reliability of intergroup differences at p <0.05; 1 — determination of the indicator according to the first calculation option (figure by the authors of this article)**

Рис. 1. Половые особенности и динамические изменения некоторых показателей внимания у лиц молодого возраста: а — показатели внимания на 1-м этапе исследования; б — показатели внимания на 2-м этапе исследования. * — достоверность межгрупповых отличий при p <0,05; 1 — определение показателя по первому варианту расчета (рисунок авторов данной статьи)

Thus, a study of gender differences in cognitive functions and the effects of various levels of intellectual load revealed that short-term memory scores were higher among women, while attention scores were higher among men. Maximum dynamic changes in these indicators under the influence of intense cognitive loads were observed in the group of men, indicating a greater reserve of their cognitive capacity [17].

The study of asthenia indicators revealed the following patterns. At the first stage of the study, under a baseline level of psychoemotional stress, the maximum values for all indicators under study were observed in the group of women: "General Asthenia" — 12.93±0.76 conventional units, "Physical Asthenia" — 10.83±0.65 CUs, "Psychological Asthenia" — 11.06±0.78 CUs, "Reduced Activity" — 12.73±0.90 CUs, and "Decreased Motivation" — 10.34±0.75 CUs ($p < 0.05$). However, during the second stage of the study, which took place during the exam period under the influence of intense stress, the greatest increase in these scores was observed in men: "General Asthenia" — 22.32%, "Physical Asthenia" — 19.17%, "Mental Asthenia" — 39.58%, "Reduced Activity" — 37.75%, and "Decreased Motivation" — 30.25%. The dynamics and relationship between gender and asthenia indicators are presented in Fig. 2.

Consequently, the greatest influence of intellectual workload and stress factors on asthenia indicators was observed in men, despite initially higher values in women, indicating that men adapt to stressors less effectively [18].

When studying the influence of psychological and cognitive load and gender on students' emotional balance, the following patterns were identified regarding indicators of reactive states . In the first stage, the "Interest" indicator was highest in men, reaching 24.79±0.88 units, whereas the "Aggression," "Anxiety," and "Depression" indicators were highest in women, amounting to 11.84±0.35; 17.32±0.58 and 14.01±0.47 CUs, respectively ($p < 0.05$). During the second stage of the study, influenced by stress, an increase in the "Aggression," "Anxiety," and "Depression" scores was observed in both groups. Women's scores increased by 7.94, 14.04, and 6.23%, respectively, while men's scores increased by 2.92%, 10.72, and 11.40%, respectively. The "Interest" score increased by 7.15% in men and decreased slightly in women during the second stage ($p < 0.05$).

With regard to personality characteristics of emotional balance, such as "Curiosity," "Aggressiveness," "Anxiety," and "Depression," no statistically significant

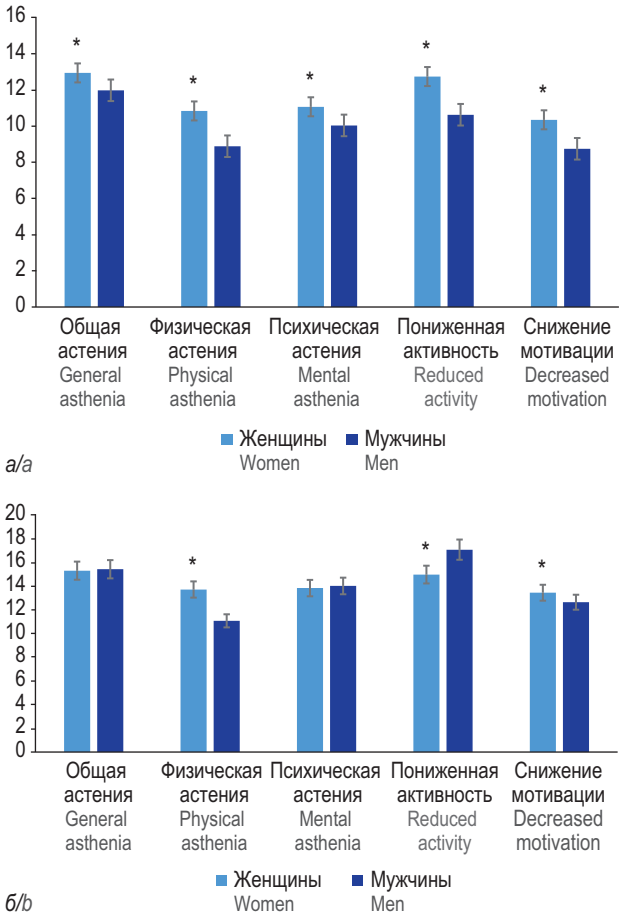


Fig. 2. **Sexual characteristics and dynamic changes in asthenia indicators in young people: a — indicators of asthenia at the 1st stage of the study; b — indicators of asthenia at the 2nd stage of the study.* — reliability of intergroup differences at $p < 0.05$ (figure by the authors of this article)**

Рис. 2. Половые особенности и динамические изменения показателей астении у лиц молодого возраста: а — показатели астении на 1-м этапе исследования; б — показатели астении на 2-м этапе исследования. * — достоверность межгрупповых отличий при $p < 0,05$ (рисунок авторов данной статьи)

changes were observed under stress. The increase during the exam period was less than 1% for all indicators in both groups.

Thus, the greatest impact on emotional balance, stress levels, and cognitive load was observed in women, while their personality traits remained virtually unchanged under the influence of these factors [19].

In the third stage, 60 participants were divided into groups based on the stimulation method. Changes in cognitive functions were characterized by the following features. The greatest increase in the short-term memory score was observed in the first (dual

stimulation) and fourth (neurostimulation games) groups, it amounted to 10.07 and 11.11%, respectively. The minimum increase was observed in the second group (control), amounting to 3.53% . There were no statistically significant differences in attention indicators between the groups using stimulation. However, a slight decrease was observed in the control group. For example, the “Attention Concentration” measure decreased by 16.04%, the “Visual Memory Capacity” measure by 12.17%, and the “Information Processing Speed” by 7.02% ($p < 0.05$).

When investigating the effect of various stimulation options on students’ emotional balance, no statistically significant differences were found between the stimulation options and their impact on reactive states and personality characteristics. Changes identical to the dynamics of emotional balance were observed with regard to indicators of asthenia.

When conducting REG at Stage 1 under a baseline level of psychological and cognitive load, no statistically significant correlation was found with indicators of cognitive functions and emotional balance. The effect of gender was determined for the “Venous Outflow Index” indicator, since its value was lower in men than in women,. Moreover, this difference increased during functional tests: the mean value of indicators for all leads during resting recordings was 0.61±0.03 CUs in men and 0.67±0.01 CUs in women . When recording REG during head rotation to the left he mean value of indicators was 0.58±0.02 and 0.64±0.01 CUs, respectively; during head rotation to the right — 0.61±0.02 and 0.64±0.01 CUs, respectively; during the orthostatic test — 0.57±0.03 and 0.62±0.03 CUs, respectively ($p < 0.05$). The data are presented in Fig. 3.

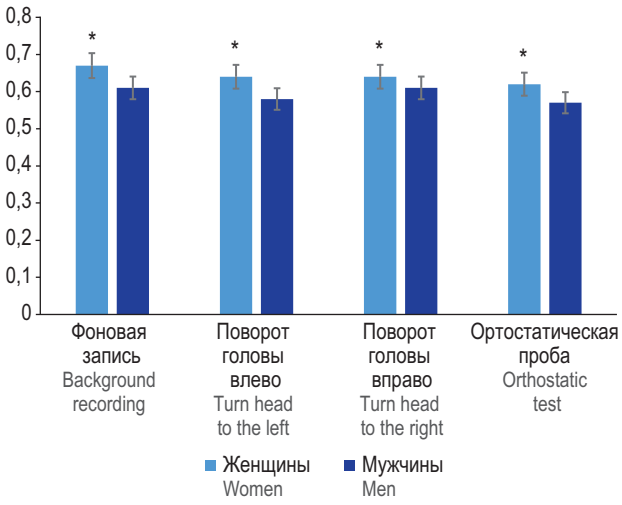


Fig. 3. **Sexual characteristics of cerebral blood flow (Venous outflow index) at 1st stage. * — reliability of intergroup differences at $p < 0.05$ (figure by the authors of this article)**

Рис. 3. Половые особенности показателей мозгового кровотока (индекс венозного оттока) на 1-м этапе. * — достоверность межгрупповых отличий при $p < 0,05$ (рисунок авторов данной статьи)

A repeat REG recording during the third stage of the study, following stimulation, also demonstrated the absence of a statistically significant correlation with indicators of cognitive function, emotional balance, and the type of stimulation used. During this stage, all groups showed a slight increase in large and medium vessel tone and a minor increase in the “Venous Outflow Index” [20].

DISCUSSION

This study revealed the following patterns. Men exhibited more pronounced cognitive reserves, as evidenced by the greatest increase in short-term memory and attention scores during the phase of intense intellectual exertion. At the same time, men demonstrate greater resilience to baseline levels of stress and cognitive load, indicating greater stability of adaptive mechanisms under standard conditions. However, as psychocognitive load increases, they exhibit a marked rise in asthenia indicators, which may indicate limited compensatory resources under prolonged exposure to stressors. In addition, men typically exhibit lower values of the rheoencephalographic parameter “venous outflow index” in all leads, both at rest and during functional tests, reflecting characteristics of cerebral blood flow that may influence the dynamics of cognitive processes.

By contrast, women show a higher predisposition to asthenic manifestations under baseline stress levels; however, as the intensity of the stressor increases, they demonstrate better adaptation and less variability in their emotional state. The greatest influence of emotional stress is manifested in changes in reactive states while personality characteristics remain stable. These data indicate greater flexibility and adaptability of emotional-cognitive mechanisms in women when activity conditions change.

CONCLUSIONS

1. The study of short-term memory, attention, and emotional balance revealed greater cognitive reserves and less lability in reactive states among men.

2. Gender features of cognitive status and emotional balance in young adults are associated with adaptive characteristics under varying degrees of intellectual and stress load. Greater adaptation to increased stress levels was observed in women, and more adequate adaptation to baseline stress was observed in men.

3. Individual differences in cerebral blood flow had no discernible effect on cognitive functions, emotional balance, or indicators of asthenia.

4. Compared to other neurostimulation methods, dual stimulation and monocorrection using games had the greatest effect on cognitive functions.

Thus, the obtained data can serve as a basis for further research aimed at optimizing approaches to maintain cognitive and emotional health. These approaches should take gender-specific characteristics into account. They should also guide individual educational pathways tailored to students' gender characteristics and the development of mobile applications to optimize daily routines for efficient time management, improving the effectiveness of learning, and preventing the development of asthenic syndrome and other functional disorders [21–23]

ADDITIONAL INFORMATION

Author contribution. L.A. Avtaykina — development of the study concept, writing the original text; A.V. Budanova — collection of data, participation in the analysis and writing of the text; D.D. Boriskin — conducting the experimental study; D.V. Puzakova — performing the statistical analysis; E.V. Arsentyeva — scientific and technical editing; T.I. Vlasova — development of the study model, evaluation of intermediate and final results.

All authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

Competing interests. The authors declare that they have no competing interests.

Consent for publication. Written consent was obtained from the patient for publication of relevant medical information within the manuscript.

ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. Л.А. Автайкина — разработка концепции исследования, написание исходного текста; А.В. Буданова — сбор материала, участие в осуществлении анализа и написания текста; Д.Д. Борискин — проведение экспериментального исследования; Д.В. Пузакова — выполнение статистического анализа; Е.В. Арсентьева — научное и техническое редактирование; Т.И. Власова — построение модели исследования, оценка промежуточных и окончательных результатов.

Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией.

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

Информированное согласие на публикацию. Авторы получили письменное согласие обследуемых на публикацию медицинских данных.

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