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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.
GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.
ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგ-ლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ,რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენ-ტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემა-ჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტო-სურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სუ-რათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხო-ური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანე-ლის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შე-ჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

Содержание:

COMPARATIVE ASSESSMENT OF ATHLETES' AUTONOMIC REACTIVITY BY HRV INDICATORS IN FUNCTIONAL TESTS OF VARIOUS DIRECTIONS

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Abstract.

Aim: The purpose of the research is to study and comparatively evaluate the changes in HRV indicators in functional tests of various directions.

Methods: HRV was studied in 50 elite athletes (athletics, wrestling, judo, football) , at age 20-26 years old. The research was held in the scientific research laboratory of the Armenian State Institute of Physical Culture and Sport using the hardware - software complex "Varikard 2.5.1, Iskim – 6.2. The studies were carried out in the morning, in the preparatory phase of the training process, at rest and during functional testing. In orthotest HRV was recorded at rest 5 min supine followed by 5 min standing. 20 minutes later, a treadmill test was carried out on Treadmill Proteus LTD_7560 with a gradually increasing load (1 km/h per minute) until exhaustion. The duration of test was 13-15 minutes, HRV recorded after test 5 min supine. HRV time indicators - HR(b/m), MxDMn(ms), SI (un) and frequency (spectral) indicators - TP (ms2), HF (ms2), LF (ms2), VLF(ms2) are analyzed.

Results and conclusion: The degree and direction of changes in HRV indicators are connected with the different type of stress factors, their intensity and duration. The HRV time indicators in both tests change unidirectionally: sympathetic activation causes an increase in heart rate, a decrease in the variation range MxDMn and an increase in the stress index SI, with the greatest degree of shifts in the treadmill test. The spectral indicators of HRV in both tests vary in different directions. In orthotest, the vasomotor center is activated, expressed by an increase in LF wave amplitude against the background of a decrease in the HF wave, but without a significant reaction from the total power of the TP spectrum and the humoral-metabolic component VLF. With the treadmill test, there is an energy-deficient state, expressed by a sharp decrease in TP wave amplitude and all spectral indicators reflecting the activity of individual management levels of heart rhythm control.

The picture of correlation links emphasizes the balanced functioning of the autonomic nervous system at rest, increased sympathetic activity and regulation centralization in orthotest, as well as an imbalance of autonomic regulation in treadmill test.

Key words. Heart rate variability, autonomic regulation, functional testing, athletes.

Introduction.

Assessment of the autonomic mechanisms of heart rate regulation is one of the intensively studied problems in sports physiology and medicine [1,2], since the state of the adaptive and reserve capacity of the athletes' body is associated with the degree of tension and functioning level of regulatory systems [3-7]. The heart rate variability (HRV) is an integral indicator of the body's homeostasis and reflects autonomic regulation of the body and balance of the autonomic nervous system (ANS) [2,8].

Currently, HRV assessment is the most informative method of rapid control of the functional state of the athlete's body [9-11]. This method is many times superior to heart rate monitoring, traditionally used to monitor exercise in sports. HRV studies have shown that various individual features of the autonomic regulation of the circulatory system are revealed at the same heart rate (HR) in athletes [12], and HR is not an indicator that fully characterizes the effect of physical activity on the functional state of the body [13]. A characteristic feature of this method is its non-specificity in relation to nosological forms of pathology and high sensitivity to a wide range of influences. The cardiovascular system (CVS) reacts to the slightest changes in the needs of organs, providing them with sufficient blood supply and is a universal indicator of the adaptive activity of the whole organism [14].

Functional testing is an important part of HRV research, as it allows to determine the adaptive reserves of the CVS. In this regard, the study and assessment of the functional state of athlete's body and cardiovascular autonomic regulation are always relevant, because they help to identify the level of functional fitness of athletes, which is one of the important determinants of training adaptations of athletes [8,15].

The value of HRV indicators obtained as a result of functional testing are often assessed by researchers in different ways [16-18], since they depend on the position of the body, the direction of the study, the form, intensity, and duration of influence of stress factors.

At the same time, qualitative and quantitative characteristics are given, but no clear idea is created about the degree of tension in the functioning of regulatory systems, the expense of functional reserves and the range of response to various stress factors.

Purpose of the research is to study and comparatively evaluate the changes in HRV indicators in functional tests of various directions.

Material and methods.

The sample consisted of 50 elite athletes from different disciplines (athletics, wrestling, judo, football). The mean age was 22.6 years (range 20–27). The research was held in the scientific research laboratory of the Armenian State Institute of Physical Culture and Sport using the hardware - software complex "Varikard 2.5.1, Iskim – 6.2. for cardiointervalogram processing and HRV analysis. A prerequisite for the correct assessment of HRV indicators and the state of autonomic balance at rest is the presence of a sinus rhythm.

The studies were carried out in the morning, in the preparatory phase of the training process, at rest and during functional testing, including orthotest and maximum treadmill test until exhaustion. All athletes gave their written consent to participate in the study.

Orthotest was carried out in accordance with the standard scenario (HRV recorded at rest during 5 min supine followed by 5 min standing). 20 minutes later a treadmill test was carried out on Treadmill Proteus LTD_7560 with a gradually increasing load (1 km/h per minute) "to the point of failure". The duration of the test was within 13-15 minutes, HRV was recorded after test during 5 min supine.

The following indicators are analyzed: time indicators - HR(b/m), MxDMn(ms), SI (un) and frequency (spectral) indicators - TP (ms2), HF (ms2), LF (ms2), VLF(ms2).

MxDMn, variation range, reflects the degree of dispersion of cardio intervals in the studied dynamic series. This indicator corresponds to the TINN, adopted in Europe and USA.

SI, stress index, reflects the degree of tension of regulatory systems, the activity of the mechanisms of sympathetic regulation and the state of the central circuit of regulation.

TP, the total power of spectrum, reflects the total activity of neurohumoral influences on the HR .

HF, respiratory wave, is the high-frequency component of the spectrum, reflects the level of parasympathetic influences on the HR.

LF, the low-frequency component of the spectrum, reflects the level of vasomotor center activity.

VLF, the very low-frequency component of spectrum, reflects the level of activity of the sympathetic link of the regulation, characterizing the influence of suprasegmental higher autonomic centers on the cardiovascular subcortical center.

The mentioned autonomic indexes indicate the level of activity of autonomic regulatory systems.

Statistical data analysis was performed using the PYTHON 2022 software program. We used Student's t-test and selected p-value as a criterion of significance. Regarding correlation checking, we used Pearson correlation.

Results and Discussion.

To obtain reliable information about the state of regulatory systems, we carried out a study of autonomic balance at rest and autonomic reactivity during functional testing. In order to test the capabilities of the HRV method in assessing the autonomic reactivity of athletes, along with the generally accepted orthotest, a maximum stress test on a treadmill was used. At the same time, we were interested in the question of the direction and degree of shifts in HRV indicators that occur in the response to various functional tests.

As can be seen from Table 1 the HRV indicators obtained at rest reflect the picture of the autonomic balance between the sympathetic and parasympathetic arms of the ANS. HR value corresponds to the average level of heart rate in athletes. The magnitude of MxDMn and SI indicators are also in the range of optimal levels [15]. The stress index adequately reflects the total effect of cardiac regulation, which follows from its formula (SI = AMo/2Mo x MxDMn). The Mo and AMo indicators reflect the activity of the sympathoadrenal system, and the MxDMn indicator reflects the level of parasympathetic regulation. Thus, the degree of tension of regulatory systems is revealed.

As can be seen from Table 1 and Figure 1, during the tests, there is a natural increase in the HR and SI index, most expressed in the treadmill test. It should be noted that small changes in heart rate hide a different degree of tension of cardio regulatory systems, since HRV is associated not only with the tonic influence of the nervous system, but also with the inclusion of suprasegmental structures. Variations of the SI value in various states are significantly nonlinear. With increasing stress levels this indicator begins to increase on an ever-increasing scale, reflecting the degree of predominance of the activity of central regulatory mechanisms over autonomous ones.

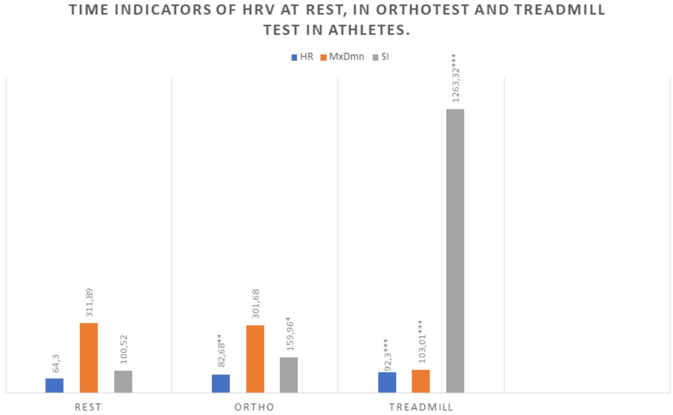

Figure 1. *Time indicators of HRV at rest, in Orthotest and Treadmill test in athletes.*

It is interesting to note that due to the predominance of sympathetic activity, the magnitude of the variation range MxDMn almost does not change during the orthotest, but significantly decreases in the treadmill test. The increase in sympathetic regulation during a heavy stress is revealed by the stabilization of the rhythm, a decrease in the dispersion of the duration of cardio intervals and an increase in the number of the same type intervals.

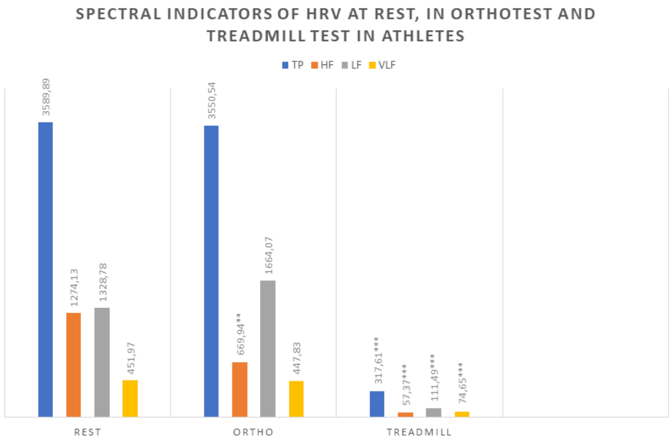

Figure 2. *Spectral indicators of HRV at rest, in Orthotest and Treadmill test in athletes.*

Figure 2 shows the data of the spectral analysis of HRV, which gives quantitative assessment of periodic processes in the heart rhythm. Using the mathematical convert Fourier (Fast Fourier

Table 1. *Average HRV indicators at rest, in Orthotest and Treadmill Test in athletes.*

Indicators	**HR** b/m	**MxDMn** ms	**SI** un	**TP** ms2	**HF** ms2	**LF** ms2	**VLF** ms2
Rest	64,30 ± 1,2	311,89 ± 15,3	100,52 ± 17,7	3589,89 ± 352,3	1274,13 ± 152,9	1328,78 ± 185,7	451,97 ± 32,8
Orto	82,68 ± 1,8**	301,68 ± 23,0	159,96 ± 23,4*	3550,54 ± 516,8	669,94 ± 137,1**	1664,07 ± 203,5	447,83 ± 32,8
Reliability between Rest and Orto							
Treadmill	92,30 ± 1,5***	103,01 ± 6,4***	1263,32 ± 279,6***	317,61 ± 38***	57,37 ± 10,6***	111,49 ± 14,8***	74,65 ± 10,6***
Reliability between Rest and Treadmill							

*Note. *-reliability($p<0,05$); **- reliability ($p<0,01$); ***- reliability ($p<0,001$)*

Transform), it becomes possible to study the wave structure of the HRV in the form of the total power of the TP spectrum with its components: HF, LF and VLF waves. The wave frequency of the rhythm reflects the influence of the central and autonomous regulation circuits on the sinus node.

The total power of the TP spectrum in the physiological sense is a reserve of adaptive energy, and its components reflect the activity of separate levels of heart rhythm control and can be distributed differently. This mainly concerns HF and LF waves. As mentioned above, the respiratory component HF reflects the level of parasympathetic influences on the heart rate and the activity of the "autonomous" regulation circuit [3,19], the LF wave reflects mainly sympathetic influences, but the parasympathetic tone also affects its formation [19].

Usually, the HF wave amplitude is more than LF. According to our data, the predominance of LF over HF is visible, which indicates some tension of the sympathetic arm of the ANS in our sample of athletes. However, the actual values of HF and LF, as well as all spectral indicators, are within normal limits. The VLF wave reflects the influence of the psycho-emotional and functional state of the cerebral cortex and its significance is associated not with sympathetic catecholamines, but with the activity of the renin-angiotensin-aldosterone system (RAAS) [20].

As it follows from Figure 2, in orthotest there is no visible change in the spectral parameters TP and VLF and there is an expressive decrease in the respiratory wave HF.

At the same time, a small unreliable increase in the LF wave with an increase in its predominance over HF is noted. These changes indicate a clear decrease in parasympathetic activity against the background of some increase in sympathetic activity and activation of the vasomotor vascular center.

It is noteworthy, that in the maximum stress test, there is a significant reliable decrease in the values of all spectral indicators. A decrease in the amplitude of the TP wave represents a progressive increase in sympathetic activity, an increase in the centralization of heart rate control, and a decrease in the reserve of adaptive energy. The predominance of the LF wave over HF remains.

The analysis of changes in the size of the VLF wave during functional testing shows a significant decrease in its amplitude during the treadmill test, which is associated with the predominance of central control mechanisms and developing energy shortage. However, it is noteworthy that the amplitude of the VLF wave prevails over the HF wave, which was observed neither at rest nor in orthotest. The observed changes, indicate that in case of treadmill test increased VLF share in the reduced total spectrum , in our opinion, reflects the participation of the humoral-metabolic system in regulating the adaptation to prevent complete energy shortage. VLF waves, reflecting the influence of supra-segmental higher autonomic centers, are a sensitive indicator of the control of energy-metabolic processes.

The degree and direction of changes in HRV indicators during functional tests are connected with the various types of stress factors. The transition from a supine position to a standing position in orthotest is not a noticeable burden for a healthy person, however, it has a mobilizing effect since there is an autonomic support for changing the body position and maintaining a new position. The transition to a standing position causes a gravitational rearrangement of blood. It leads to a change in the vascular tone of the lower and upper parts of the body and to the activation of the vasomotor center, which performs a specific function of controlling vascular tone, receiving information both from the periphery and from higher levels of control.

At the same time, as we see, the activity of the sympathetic arm of the ANS increases, which is expressed by different degrees of increase in HR, SI, LF and a decrease in HF.

In other words, adaptation to orthostasis is achieved by increasing the sympathetic and decreasing the parasympathetic components and with internal shifts of the HF and LF spectral components, but without a significant reaction from the overall power of the TP spectrum and the humoral-metabolic component VLF.

During the period of intense physical activity in the maximum stress test on treadmill, a considerable mobilization of energy resources, cardiovascular, respiratory, and other systems occur. In this situation, homeostatic indicators can deviate greatly from their rest level, as if carrying out a process opposite to maintaining homeostatic balance, but necessary for carrying out activities in an extreme state. At the same time, as we see, autonomic reactions are expressed by a distinct increase in sympathetic regulation, the mobilizing effect of which is shown by the stabilization of the rhythm, a decrease in the variation range of cardiac intervals, a sharp increase in the amount of the stress index. A sharp decrease in the amplitude of the TP wave, which shows the reserve of adaptive energy, reflects an energy-deficient state. This is evidenced by the unidirectional decrease in the amplitude of all spectral indicators.

For a more thorough comparative assessment of the results obtained, we conducted a correlation analysis between various HRV indicators at rest, in orthotest and treadmill tests. Analysis of the results showed that at rest (Figure 3) a considerable positive and reliable correlations were found between a number of HRV indicators. The highest level of positive correlation is observed between the time indicator MxDMn and the spectral indicators TP (r = 0,85; p<0,01), HF (r =0,84; p<0,01), as well as between the spectral indicators TP and HF (r =0,87; p<0,01), which reflects the predominance of parasympathetic regulation at rest. The correlation between MxDMn and spectral indicators LF (r =0,59; p<0,01), VLF (r =0,61; p<0,01), as well as between Tp and LF (r =0.75; p<0,01), VLF (r =0.51; p<0,01) is expressed to a less degree. On the same level, there is a negative correlation between SI and MxDMn (r =-0,65; p<0,01), SI and TP (r =-0,51, p<0,01). The level of correlation between HRV indicators shows how balanced the functioning of the autonomic nervous system is between its two arms— sympathetic and parasympathetic.

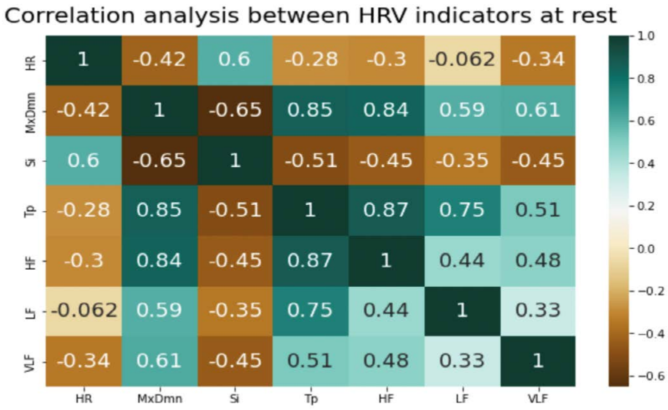

Figure 3. *Correlation analysis (heatmap) between HRV indicators at rest.*

The picture of correlation links in orthotest and treadmill test is of great interest (Figures 4 and 5). In orthotest, the degree of correlation links increases between MxDMn and spectral indicators LF (r = 0,85; p<0,01), VLF (r = 0,7; p<0,01), reflecting sympathetic activation. Though the physiological meaning of MxDMn is associated with the activity of the parasympathetic arm of the ANS [15,21], however, it is closely related to the state of the regulatory systems of the organism. Any functional changes in the body are immediately reflected primarily in the value of MxDMn. It reflects the total effect of heart rate regulation by the ANS, which is confirmed by the data of correlation analysis in orthotest. The relation also increases between the SI stress index, which characterizes the activity of sympathetic regulation mechanisms and the state of the central regulation circuit, and the LF indicator (at rest r = -0.35; p<0,05; in orthotest r = - 0,49, p<0,01), as well as between SI and VLF (at rest r = -0.45; p<0,01, in orthotest r = - 0,71; p<0,01), intraspectral connections increase too. All the observed changes indicate in favor of strengthening sympathetic activity and centralization of regulation.

In treadmill test, the degree of correlation between MxDMn and spectral indicators LF, VLF increases approximately to the same extent as in orthotest, however, the correlation links between MxDMn and HF (at rest r =0,84; p<0,01; in treadmill test r = 0,65; p<0,01), MxDMn and SI (at rest r = -0,65; p<0,01; in treadmill test r = -0,55; p<0,01) decreases noticeably, and the correlation links between SI and HF almost disappears (at rest t= -0,45; p<0,01; in treadmill test r = -0.08; p<0,01), which reflects the complete dominance of the centralization of control process and the disbalance of autonomic regulation. There is also a difference between intraspectral links. The correlation link between HF and TP (at rest r = 0,87; p<0,01; in treadmill test r = 0.69; p<0,01) visibly reduces, and the link between TP and VLF (at rest r = 0,51; p<0,01 in treadmill test r = 0,84; p<0,01) significantly increases, which once again emphasizes the high degree of activation of central regulatory mechanisms due to the activity of the RAAS system.

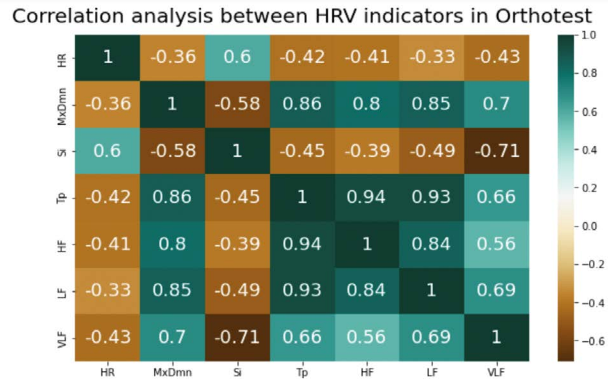

Figure 4. *Correlation analysis (heatmap) between HRV indicators in Orthotest.*

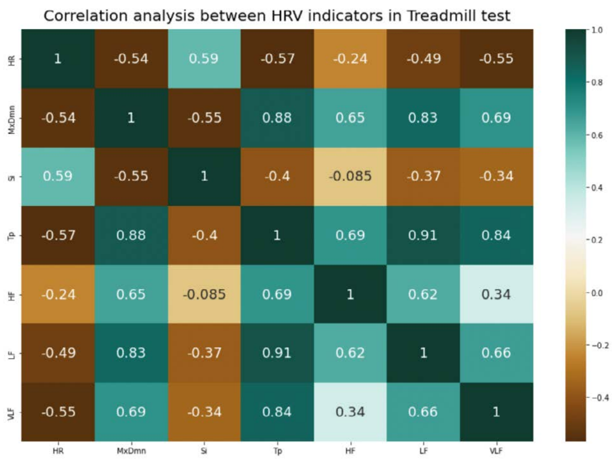

Figure 5. *Correlation analysis (heatmap) between HRV indicators in Treadmill test.*

Conclusion.

In stressful situations, there is a regular decrease in regulatory and adaptive capabilities, an increase in the intensity of all organs and systems functioning. At the same time, the degree of changes is related to the form, intensity, and duration of stress factors.

As shown by a comparative assessment of HRV indicators, activation of the sympathetic arm of the ANS during tests is revealed, firstly, as a non-specific unidirectional mobilizing reaction to various stressors, which is expressed in changes in time indicators. This is an increase in heart rate, a decrease in the variation range of MxDMn and an increase in the stress index

SI with the greatest degree of shifts in treadmill test. Secondly, sympathetic activation is revealed by a specific multidirectional reaction, expressed in changes in spectral indicators, which is related to the peculiarity of the factors causing stress reactions.

During orthotest, in response to a change in body position, the vasomotor center is activated, which is expressed by an increase in the amplitude of the LF wave against the background of a decrease in the HF respiratory wave. And with the treadmill test, in response to strenuous physical activity until exhaustion, an energy-deficient state arises, which is expressed by a sharp decrease in the amplitude of all spectral HRV indicators reflecting alarm response to stress. The above-mentioned changes reflect the physiological meaning of spectral analysis, which is to assess the activity of individual management levels of heart rhythm control.

HRV has a significant potential for assessing the role of autonomic mechanisms of heart rate regulation in athletes. Further longitudinal studies are necessary to determine the sensitivity and predictive value of HRV in various functional tests.

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РЕЗЮМЕ

Целью исследования является изучение и сравнительная оценка изменений показателей ВСР при функциональных пробах различной направленности.

Методы. Произведено изучение ВСР у 50 высококвалифицированных спортсменов (athletics, wrestling, judo, football) 20–26 лет. Исследование проведено в научно-исследовательской лаборатории Государственного института физической культуры и спорта Армении с помощью **аппаратно – программного комплекса «Варикард 2.5.1, Иским – 6.2** . Исследования проводились утром в подготовительном периоде подготовки в покое и

при фунциональном тестировании.При ортопробе ВСР регистрировалась в течение 5 минут лежа и 5 минут стоя). Через 20 мин выполнялся тредмилтест на Treadmill Proteus LTD_7560 со ступенчато-возрастающей нагрузкой (по 1 км/ч в минуту) «до отказа». Длительность нагрузки в пределах 13-15 мин. ВСР регистрировалась в течение 5 минут после теста в положении лежа. Были проанализированы временные показатели ВСР: HR(уд/мин), MxDMn(мс2), SI (мс2), а также спектральные показатели ВСР: TP (мс2), HF (мс2), LF (мс2), VLF(мс2).

Результаты и заключение. Степень и направленность изменений показателей ВСР при проведенных функциональных пробах связаны с различной природой стрессорных факторов, их интенсивностью и длительностью воздействия. Временные показатели ВСР в обоих тестах изменяются однонаправленно: симпатическая активация вызывает учащение ЧСС, уменьшение вариационного размаха MxDMn и увеличение стресс-индекса SI, с наибольшей степенью сдвигов при тредмилтесте. Спектральные показатели ВСР в обоих тестах изменяются разонаправленно. При ортопробе активизируется вазомоторный центр, что выражается ростом амплитуды волны LF на фоне снижения дыхательной волны HF, но без существенной реакции со стороны общей мощности спектра TP и гуморально-метаболической составляющей VLF . При тредмилтесте возникает энергодефицитное состояние, выражающееся резким снижением амплитуды волны TP и всех спектральных показателей, отражающих активность различных уровней управления ритмом сердца.

Картина корреляционных взаимосвязей подчеркивает сбалансированность работы вегетативной нервной системы в покое, усиление симпатической активности и централизации регуляции при ортотесте , а также дисбаланс вегетативной регуляции при тредмилтесте.

Ключевые слова: вариабельность сердечного ритма, вегетативная регуляция, функциональное тестирование, спортсмены