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**Bakunovskiy O. M., Babak S. V., Poltoratska I. Y.****METHODS OF SIMULTANEOUS STUDY OF CENTRAL AND PERIPHERAL HEMODYNAMICS DURING DOSED PHYSICAL EXERTION IN LABORATORY CONDITIONS: ORGANIZATION AND SETTING****National University of Ukraine on Physical Education and Sport (Kyiv, Ukraine)****s.babak.s.1234@gmail.com**

*The organization and implementation of the methodology for the simultaneous research of central hemodynamics and hemodynamics in the lower limbs and in visceral organs – the liver and spleen, which have a special blood supply, was carried out in laboratory conditions, with dosed physical exertion. To conduct the research, the participation of a team of researchers (one manager and 6 researchers) who work with the subject (located on a bicycle ergometer) is necessary. The main device for studying hemodynamics is a rheograph: computer diagnostic complex «ReoCom XAI-Medika», 8-channel. The research type «Rheography of the lower limbs + thoracic abduction» was applied. The manufacturer of the device does not provide the type of study «Rheography of the liver + spleen», but we carried it out, since the design of the device and its software allow the user to create new types of rheography studies. And the study of the effect of physical exertion on the hemodynamics of the named organs is expedient given the fact that they have the function of a blood depot, which is included in the redistribution of the volume of circulating blood during physical exertion.*

*Approbation of the method, which was carried out with the involvement of 22 volunteers, turned out to be successful and effective. We obtained data that simultaneously showed the state of central and peripheral hemodynamics during dosed physical exertion in laboratory conditions.*

**Key words:** organization, implementation and approbation of the method, central hemodynamics, hemodynamics of the lower limbs, liver and spleen.

**Connection of the publication with planned research works.**

The work was carried out in accordance with the plan of research works of the department of medical and biological disciplines of the National University of Ukraine on Physical Education and Sport «Influence of endogenous and exogenous factors on the course of adaptive reactions of the body to physical exertion of various intensities» (state registration number 012U108187).

**Introduction.**

The performance of athletes and their achievement of high sports results is mainly determined by the functioning of the cardiovascular system. Physical activity of different intensity, duration and strength contribute to the expansion of the body's adaptive capabilities.

In recent years, scientists in the field of sports physiology have paid increased attention to methods of researching the functional state of the circulatory system (Bergtraum D. I., 2012, 2013). Peculiarities of central and peripheral hemodynamics are studied, depending on physical loads and in athletes of various specializations [1, 2, 3, 4, 5, 6].

To date, there are data on the results of studies of central and peripheral hemodynamics in weightlifters (Yashchenko A.T., 2001), which show tension on regional blood circulation. Other scientists have identified hemodynamic disorders in the limbs of track and field athletes (in particular, runners of various distances), as well as female athletes engaged in freestyle wrestling at a high level of qualification (Bergtraum D. I., 2002; Zusmanovych F. N., Brudnykh V. A., et al., 2002).

There is an interesting research of the hemodynamics of the lower limbs in highly skilled high jumpers (L.S. Vovkanych, 2011). Scientists conducted a comparative analysis of blood flow in the lower legs in swimmers and in track and field athletes. There are also studies of the peculiarities of brain hemodynamics in athletes, central and peripheral hemodynamics in basketball players, soccer players, etc. (Sarafinyuk L.A., Lezhnyova O.V., Kachan V.V., 2017). Comparative characteristics of central and peripheral hemodynamics in sportswomen with different methods of statics were conducted (Shkopinsky E.A. et al., 2008). Blood circulation studies were conducted in obese people during physical exercise [7, 8, 9, 10].

Scientists who research the activity of the heart and the state of central and peripheral blood circulation in athletes have accumulated a lot of controversial scientific data, so this issue requires further study using improved research methods.

Skeletal muscles used during exercise need adequate blood supply. At the same time, exercise poses a unique challenge to the liver, as the metabolic demands of strained muscles require the liver to mobilize energy reserves, process metabolites, and convert excess toxic compounds into harmless forms [11]. The participation of the immune system organs in the processes of adaptation of the body under conditions of increased physical activity was studied as early as the 20th century (Surkina I.D. et al., 1980, 1980; Levando V.A. et al., 1983; Dembo A.G., 1984; Meerson F.Z. et al., 1988; I.D. Surkina I.D. et al., 1991). It has been proven that significant changes occur in the organs of the immune system in athletes. However, there is little data about the spleen,

and especially about its blood supply during physical exertion (Sapin M.R., Samoilov M.V., 1988). The effect of high physical exertion on the spleen in animals was studied (Hsia C. C. W. et al., 2007). There are research on the redistribution of the volume of circulating blood from less loaded organs to actively working ones. But this problem needs to be detailed in relation to the connection with different load power.

There is no information in the scientific literature about the method of simultaneous research of central and peripheral hemodynamics during physical exertion.

### The aim of the study.

To organize, implement, describe and test the method of the simultaneous research of central and peripheral hemodynamics during dosed physical exertion in laboratory conditions.

### Object and research methods.

The organization and implementation of the method of simultaneous research of central hemodynamics and blood supply in the limbs and visceral organs – the liver and spleen, which have a special blood supply – were carried out. Teachers and students of NUUPES and NDUU took part in the practical research process. Teachers and 7 students provided the methodology, and 22 male persons aged 18-23 participated in the research. The research was conducted in accordance with international norms of bioethics and legislation of Ukraine. All persons who participated in the research were informed about the goals, means, structure and sequence of the research and gave their consent. Venue: Scientific Physiological Laboratory of the Department of Medical and Biological Sciences of NUUPES.

The laboratory should have the following equipment:

1) bicycle ergometer: KETTLER Ergometer E3 (with a monitor that, in particular, allows to control the pace of pedaling by the number of rotations in 1 minute and the power of the load in watts) (fig. 1);

2) rheograph: 8-channel computer diagnostic complex «ReoCom XAI-Medika» (fig. 2);

3) electrode sets of two types (fig. 3):

- seven tape coil electrodes for thoracic rheography and rheography of the lower limbs,
- four flat double electrodes for rheography of the liver and spleen;

4) a personal computer that meets the requirements of the «ReoCom Operating Instructions» for installing and starting the system, with the installed software of the «ReoCom XAI-Medika» diagnostic complex [12];

5) centimeter tape for measuring interelectrode distances;

6) One-X automatic tonometer for measuring blood pressure;

7) a watch with a stopwatch to control compliance with the time parameters (cyclogram) of the «technological cycle» of the research and coordinate the actions of the research participants;

8) a stopwatch to determine the heart rate during the first 10 seconds after the end of the load.

### Research results and their discussion.

Simultaneous fixation of hemodynamics in the described organs during physical exertion is quite important. As our observations revealed,



Figure 1 – Bicycle ergometer: KETTLER Ergometer E3.

the complexity of such simultaneous measurement of hemodynamics lies, first of all, in the need to form a team of a certain, clearly defined number of researchers and the coherence of their work.

The organization of the research process begins with the preparation of the premises, equipment (described in the materials) and researchers and the subject.

The premises: should be well lit; sufficient area for the subject who is on the bicycle ergometer and the researchers who must move freely around the subject during work.

### Preparation and participation of researchers in the research process.

Manager – 1 person (female or male).

The number of researchers is 6 (female or male).

The supervisor instructs the researchers, distributes responsibilities, announces the goal, sets tasks, explains the scheme, structure and sequence of the research process.



Figure 2 – 8-channel computer diagnostic complex «ReoCom XAI-Medika».



Figure 3 – Tape coil electrode for thoracic rheography and rheography of the lower limbs (left) and double flat electrodes for rheography of the liver and spleen (right).

One of the researchers conducts a survey and informs the subject:

1. The subject can be a person – both male and female. In the case of a female, an additional survey should be conducted, taking into account the peculiarities of the physiology of the female body, which affects the results of the study. The subject fills out a questionnaire, which indicates anthropometric data, sleep patterns, food intake, etc.

2. The subject gets acquainted with the content and procedure of conducting the research and gives informed consent to participate in the research. In our study, all subjects are athletes (practically healthy individuals) who systematically undergo medical examinations.

he subject's clothes: shorts and sneakers. The subject's task: pedaling on a bicycle ergometer without prior warm-up three times for 5 minutes with 5-minute rest breaks.

Next, researchers take their places and choose equipment. The diagram of the placement option for researchers is shown in **figure 4**. In the center is a bicycle ergometer, on which the subject is placed.

Each researcher has his own responsibilities (**table**).

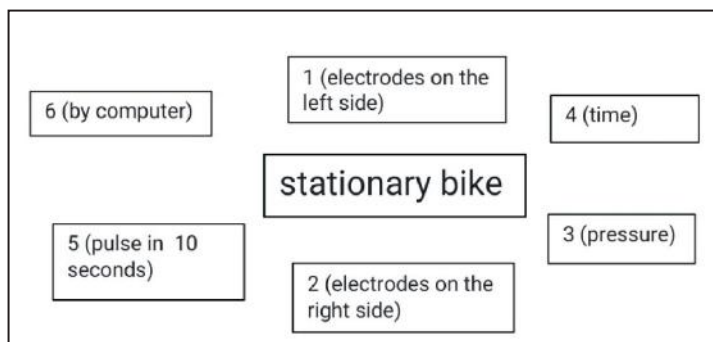


Figure 4 – Scheme of placement of the subject and researchers in the laboratory: 1, 2, 3, 4, 5, 6 – 1st, 2nd, 3rd, 4th, 5th and 6th researchers, respectively.

Installation and connection of electrodes:

- The use and placement of electrodes for the study of regional hemodynamics in visceral organs (rheography of the liver and spleen, synchronous registration, the type of study «Rheography of the liver + spleen»): double flat electrodes are placed horizontally on the front and back surfaces of the chest on the right (above the liver) and on the left (above the spleen). The center of the front measuring electrode is placed at the point of intersection of the front midclavicular line with the edge of the costal arch, the back one – at the same level along the scapular line. The current electrode is placed above the measuring electrode in front, and below it in the back. Cables with white markings are connected to the current electrodes. The right electrodes are connected to the red-marked cables of the 1st remote block of the rheograph, the left – to the red-marked cables of the 2nd. The green-marked cables connect to the coil electrodes on the right thigh and left forearm.

- The use and placement of electrodes for simultaneous research of regional hemodynamics in the lower limbs and central hemodynamics (type of research

«Reography of the lower limbs + thoracic lead»): coil electrodes are placed in the lower third of the lower leg and on the border of the upper and middle thirds of the thigh of both lower limbs symmetrically, observing the same inter-electrode distances. The electrodes on the limbs are connected to the 1st remote block of the rheograph (right leg – red marking, left leg – green marking). Cables with white marking (current) are connected to the lower «sockets» of the coil electrodes on the lower legs. For thoracic rheography (thoracic lead), ribbon coil electrodes are applied to the lower neck and chest horizontally at the level of the articulation of the sternum with the xiphoid process. The chest lead is connected to the cables of the 2nd remote unit (white marking – on external, current, tape coils, red marking – on internal, measuring). Cables with green marking are connected to the coil electrodes on the left forearm (**fig. 5**).

- After installing the electrodes, the 1st and 2nd researchers measure the interelectrode distances with a centimeter tape and report them to the 6th researcher.

- Rheography involves simultaneous recording of the actual rheogram and electrocardiogram (ECG) in

Table – Type of work of researchers

Researchers	Functions
1st and 2nd researchers	apply electrodes on certain areas of the subject's body and connected to the corresponding channels of the rheograph
3rd researcher	measures the pressure of the subject with a tonometer
4th researcher	controls the time when performing the stages of the research process
5th researcher	measures the heart rate during the first 10 seconds after the end of the exercise
6th researcher (personal computer operator)	registers (records) rheograms in accordance with the recommendations on the technique of recording rheographic signals «ReoCom Operating Instructions»

**Conducting research.**

Before starting work, the seat of the bicycle ergometer is set according to the length of the subject's legs. He has a control determination of the heart rate and blood pressure (research is started under the condition of normal values).

The physical load performed by the subject on the bicycle ergometer is dosed and increasing: the first is 50 watts, the second is 100 watts, the third is 150 watts. Each time the pace of pedaling is 60 rotations per minute. It is necessary to monitor the corresponding indicator on the display of the bicycle ergometer.

After the signal «RECORD» (given by the 6th researcher), the subject should not move or talk. The subject is not allowed to remove the electrodes on his own!

**Content of the research methodology.**

The 1st and 2nd researcher apply the electrodes and connect them to the corresponding channels of the rheograph:

- before starting loads for research in a state of rest,
- immediately after the first, second and third loads,
- 5 minutes after the third load for recording in recovery state.

one of the standard leads. Appropriate limb electrodes are used for the ECG channel.

- While the subjects are pedaling, the 1st and 2nd researchers disconnect all the cables of the remote units and remove the electrodes from the neck and limbs. Immediately after the completion of each of the loads, the removed electrodes are placed again and connected to the cables.

3rd researcher measures blood pressure with an automatic tonometer immediately after each exercise and 5 minutes after the third exercise. The results of the indicators are reported to the 6th researcher.

4th researcher keeps track of time: records 5 minutes of dosed physical activity and 5 minutes of rest and coordinates the actions of others.

5th researcher determines the heart rate by the pulse on the left common carotid artery for the first 10 seconds each time and immediately after the end of the exercise and the first 10 seconds during the recovery phase.

6th researcher (personal computer operator) enters the data of the subject into the database of the computer system, registers (records) rheograms in accordance with the recommendations on the technique of recording rheographic signals «ReoCom Operating Instructions», informs the participants of the study about the start and end of registration of each rheogram.

It should be noted that the registration of rheograms of: 1) liver and spleen and 2) lower limbs and thoracic rheogram is carried out almost synchronously. The time between these two rheographies does not exceed 10-15 seconds. During this time, there are no significant changes in the indicators of central hemodynamics, so we believe that the indicators of central and visceral hemodynamics are registered almost simultaneously.

A sample of synchronous recording of the chest rheogram and rheovasogram of the lower limbs in **fig. 6**.

It should be noted that the rheographic method is known. In particular, it is widely used in clinical practice to study blood circulation in hard-to-reach areas of the body and organs. V. A. Karelin (1957) first used this method to assess the state of peripheral blood circulation in obliterating arterial diseases. V.A. Karelin designated peripheral rheography with the term «rheovasography». Scientists of the Bogomoletz



Figure 5 – Location of electrodes on the chest (front and back view) and on the lower limb.

Institute of Physiology NAS of Ukraine made a significant contribution to the introduction of rheography as a non-invasive method of hemodynamic research. It was established that tetrapolar thoracic rheography is the most perfect method for rheographic determination of cardiac output parameters. It is for this type of research that W.G. Kudicek proposed a method for determining the minute volume of blood, which became generally accepted.

For hemodynamic studies, Ukrainian scientists use, in most cases, the ReoCom Standard computerized rheograph, manufactured by XAI-MEDIKA (Kharkiv Aviation Institute). The device allows you to conduct various types of rheographic studies, in particular, to record rheograms of different parts of the body synchronously. Rovny A.S. (2002) conducted rheographic research of only the liver in runners at different distances. Relatively many scientists have studied hemodynamics in the limbs. Regarding the rheographic research of the spleen in athletes, there are practically none of them. We used the type of study «Rheography of the lower limbs + thoracic lead», but the manufacturer does not provide the type of study «Rheography of the liver + spleen». However, the design of the device and its software allow the user to create new types of rheographic studies.

As is known, the nature of the reaction of peripheral vessels during physical exertion is determined by the degree of involvement of blood-supplied organs. During physical work, the blood supply in the involved skeletal muscles increases as a result of expansion of their blood vessels due to local influences [11].

Central and regional blood circulation is based both on the basic principles of hemodynamics and on the specific properties of blood supply to organs. We chose the liver and spleen from the visceral organs. Each of these organs has a rather specific blood supply. Portal blood circulation has a significant effect on the functioning of the organs of the abdominal cavity, as well as on central hemodynamics. At the same time, venous blood enters the liver through the portal vein and arterial blood – through the hepatic artery. The system of arteriovenous anastomoses prevents the death of hepatocytes in case of turning off either arterial or portal blood flow. Liver circulation has two networks of capillaries. The peculiarity of the portal blood circulation ensures the implementation of complex functions of the liver: exchange, detoxification and excretory [11].

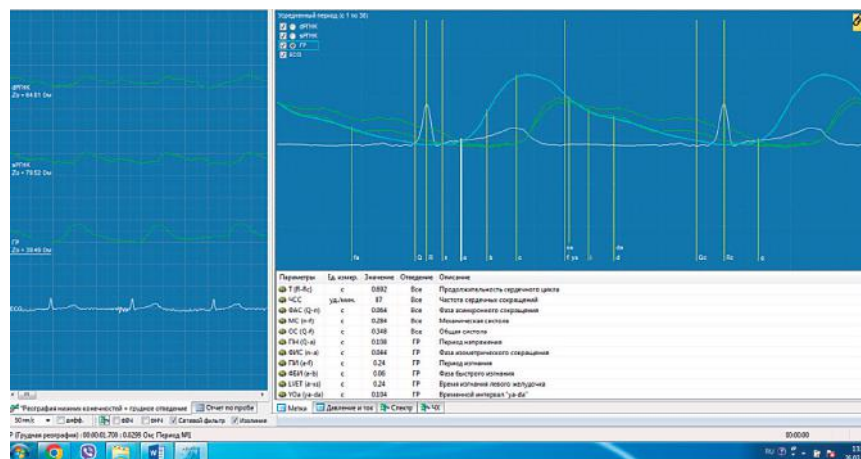


Figure 6 – Recording of the central rheogram and rheovasogram of the lower limbs.

The vascular system of the spleen also has its own characteristics. The splenic artery branches into a system of trabecular arteries, which in the white pulp are surrounded by periarterial lymphatic sheaths and splenic follicles. Central arteries in the red pulp divide into tufted arterioles and end with ellipsoidal arterioles. Ellipsoid arterioles are sphincters of the spleen, which are connected with the venous sinuses of the spleen by a system of hemocapillaries and form a system of closed blood circulation of the spleen. Another part of the capillaries opens directly into the red pulp – this is the open circulatory system of the spleen. Venous sinuses at the places of their transition into veins of the red pulp form venous sphincters of the spleen. Simultaneous contraction of the arterial and venous sphincters ensures deposition of blood in the spleen. And the relaxation of these sphincters during the contraction of myocytes pushes the deposited blood into the venous channel.

The study of the effect of physical load on the hemodynamics of the mentioned organs is expedient given the fact that they have the function of a blood depot, which is included in the redistribution of the volume of circulating blood during physical exertion.

The described technique was carried out using the above-mentioned rheograph. Rheographs of other manufacturers can be used to study hemodynamics, but in this case, when organizing the research process, it is necessary to take into account the design features of a specific device.

Approbation of the method, which was carried out with the involvement of 22 volunteers, turned out to be

successful and effective. We obtained data that simultaneously showed the state of central and peripheral hemodynamics during dosed physical exertion in laboratory conditions.

### Conclusions.

1. The rheograph device (8-channel computer diagnostic complex «ReoCom XAI-Medika») was used for synchronous research «Rheography of the lower limbs + thoracic lead» and «Rheography of the liver + spleen» in laboratory conditions with dosed physical exertion. The design of the device and its software allow creating new types of rheographic studies.

2. The simultaneous study of central hemodynamics and blood circulation in the limbs and visceral organs during dosed physical exertion is a coordinated collective work that is possible only under the conditions of a clear organization and formulation of the methodology, an adequate selection of researchers who perform their duties in a coordinated, timely and consistent manner. The number of researchers, their location around the subject and their communication with each other matters. Such a research process is developed through repeated collective action. Approbation of the proposed method was carried out with the involvement of 22 volunteers. It turned out to be successful and effective.

### Prospects for further research.

Expanding the methodical and methodological base of research will contribute to the understanding of the problem of redistribution of blood circulation in athletes of various specializations, which is necessary for improving the training process and sports performance.

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## МЕТОДИКА ОДНОЧАСНОГО ДОСЛІДЖЕННЯ ЦЕНТРАЛЬНОЇ ТА ПЕРИФЕРІЙНОЇ ГЕМОДИНАМІКИ ПРИ ДОЗОВАНИХ ФІЗИЧНИХ НАВАНТАЖЕННЯХ В ЛАБОРАТОРНИХ УМОВАХ: ОРГАНІЗАЦІЯ І ПОСТАНОВКА

Бакуновський О. М., Бабак С. В., Полторацька І. Є.

**Резюме.** Мета дослідження: організувати, поставити, описати та апробувати методику одночасного дослідження центральної та периферійної гемодинаміки при дозованих фізичних навантаженнях в лабораторних умовах.

Обладнання: велоергометр: KETTLER Ergometer E3; реограф: комп'ютерний діагностичний комплекс «Рео-Ком ХАІ-Медика» 8-ми каналний; комплекти електродів: для грудної реографії і реографії нижніх кінцівок та для реографії печінки і селезінки; персональний комп'ютер, що відповідає вимогам «Інструкції з експлуатації РеоКом» та ін.

*Результати.* Здійснили організацію і постановку методики одночасного практичного дослідження центральної гемодинаміки та кровопостачання в нижніх кінцівках і в вісцеральних органах – печінці і селезінці в лабораторних умовах при дозованих фізичних навантаженнях.

В статті детально описано: кількість дослідників, їх функції та всі етапи роботи. Головний прилад – реограф. Застосовано тип дослідження «Реографія нижніх кінцівок+грудне відведення». Виробником приладу не передбачено тип дослідження «Реографія печінки+селезінки», але ми його здійснили, так як конструкція приладу та його програмне забезпечення дозволяють користувачу створювати нові типи реографічних досліджень. Апробація методики, яка була здійснена із залученням добровольців, виявилась успішною та результативною. Нами отримані дані, які одночасно показали стан центральної та периферійної гемодинаміки при дозованих фізичних навантаженнях в лабораторних умовах.

*Висновки.* Прилад реограф (комп'ютерний діагностичний комплекс «РеоКом ХАІ-Медика» 8-ми каналний) можна використовувати для синхронного дослідження «Реографії нижніх кінцівок+грудне відведення» та «Реографії печінки+селезінки» в лабораторних умовах при дозованих фізичних навантаженнях. Одночасне дослідження центральної гемодинаміки та кровообігу в кінцівках і вісцеральних органах при дозованих фізичних навантаженнях – це узгоджена колективна робота дослідників, які злагоджено, вчасно і послідовно виконують свої обов'язки. Апробація методики, виявилась успішною та результативною.

**Ключові слова:** організація, постановка та апробація методу, одночасне дослідження центральної гемодинаміки, гемодинаміки нижніх кінцівок і вісцеральних органів – печінки та селезінки.

### METHODS OF SIMULTANEOUS STUDY OF CENTRAL AND PERIPHERAL HEMODYNAMICS DURING DOSED PHYSICAL EXERTION IN LABORATORY CONDITIONS: ORGANIZATION AND SETTING

Bakunovskyi O. M., Babak S. V., Poltoratska I. Y.

**Abstract.** *The purpose of our research:* to organize, implement, describe and test the method of the simultaneous research of central and peripheral hemodynamics during dosed physical exertion in laboratory conditions.

**Equipment:** bicycle ergometer: KETTLER Ergometer E3; rheograph: 8-channel computer diagnostic complex «ReoCom XAI-Medika»; electrode sets: for thoracic rheography and rheography of the lower limbs, and for rheography of the liver and spleen; a personal computer that meets the requirements of the «ReoCom Operating Instructions» for installing and starting the system etc.

**Results.** The organization and implementation of the method of simultaneous practical research of central hemodynamics and blood supply in the lower limbs and in visceral organs – liver and spleen in laboratory conditions with dosed physical exertion was carried out.

The article describes in detail: the number of researchers, their functions and all stages of work. The main device is a rheograph. The research type «Rheography of the lower limbs + thoracic abduction» was applied. The manufacturer of the device does not provide the type of study «Rheography of the liver + spleen», but we carried it out, since the design of the device and its software allow the user to create new types of rheography studies. The testing of the method, which was carried out with the involvement of volunteers, turned out to be successful and effective. We obtained data that simultaneously showed the state of central and peripheral hemodynamics during dosed physical exertion in laboratory conditions.

**Conclusions.** The rheograph device (8-channel computer diagnostic complex «ReoCom XAI-Medika») can be used for simultaneous research of «Rheography of the lower limbs + thoracic abduction» and «Rheography of the liver + spleen» in laboratory conditions with dosed physical exertion. The simultaneous research of central hemodynamics and blood circulation in the limbs and visceral organs during dosed physical exertion is a coordinated collective work of researchers who perform their duties in a coordinated, timely and consistent manner. Approbation of the method turned out to be successful and effective.

**Key words:** organization, setting and approbation of the method, simultaneous study of central hemodynamics, hemodynamics of the lower limbs and visceral organs – liver and spleen.

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#### Conflict of interest:

The authors declare no conflict of interest.

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