

Comparative analysis of methods for determining some hemodynamic parameters for students

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Abstract:

In physical culture and sports practice, the study of hemodynamic parameters in persons performing physical activity is an important direction of current and future planning of educational and training processes. It is possible to use instrumental and computational methods using formulas. To choose the method of hemodynamic research, there is a need to compare the reliability of the results obtained by various methods. *Research aim:* to evaluate the reliability of the students' cardiovascular system hemodynamic parameters obtained by calculation using formulas and data obtained during testing using the MedicalSoft sports testing system. *Research materials and methods.* 100 students of the Volga Research Medical University (Russia) took part in the research. Blood pressure was determined tonometrically, using an automatic tonometer «Omron M2 Basic», heart rate was recorded using a tonometer and a sports testing system MedicalSoft. The following hemodynamic indicators were used for the analysis: shock volume and total peripheral vascular resistance, which were determined by manual calculation using the Starr and Poiseuille formulas, as well as during testing of the subjects on the MedicalSoft software and hardware complex. Statistical processing of the research results was carried out using the Statistica 10.1 and Excel for Windows software package and the Blend-Altman method in accordance with the author's methodology. *Research results.* The absence of statistically significant differences between two different models for measuring hemodynamic parameters ($p > 0.05$) was found. Based on the results obtained, almost all values are within the confidence limits so, this fact gives grounds to consider the data obtained during measurement by the MedicalSoft software and hardware complex reliable. *Conclusions.* The absence of significant differences in the two methods for assessing hemodynamic parameters opens up opportunities for using the MedicalSoft system during systemic hemodynamics screening. If it is impossible to use the instrumental method, the hemodynamic functions of the body can be estimated by the calculation method.

Key Words: students, systemic hemodynamics, Blend-Altman method, sports testing system

Introduction

The state of the human body functional systems is assessed during an in-depth medical examination for admission to physical education or sports (Mischenko et al., 2020; Butakova et al., 2019; Kolokoltsev, 2021). In the process of conducting persons' performing physical activity current and prospective monitoring, it is also necessary to carry out medical and pedagogical control of the body using various monitoring methods (Budzyn et al., 2018). In assessing the functional state of the body and its adaptive qualities, an important role is assigned to the cardiovascular system, as a system limiting the volume and intensity of physical activity performed by a person (Shved, Levitska, 2018; Grassler et al., 2021; Bellenger & Buckley, 2021). Functional characteristics of the cardiovascular system indicate an overstrain of the body caused by excessive physical exertion, show the nature of the course of recovery processes (Dupuy & Dugué, 2018), which is important in the current and future planning of educational or training processes.

In-depth medical examination of persons for admission to physical education or sports is a rather time-consuming process, which makes it difficult to conduct mass screening of a large contingent of persons in a short time. This situation is noted during the mass medical examination of students at the beginning and at the end of the academic year. Therefore, it becomes urgent to find ways to quickly and reliably assess the functional state

of the body using non-invasive diagnostic complexes (Adams et al., 2018; Aparecida Maria Catai et al., 2020). One of them is the complex «MedicalSoft Sports Testing System» (MS FIT PRO 01 variant, Moscow, Russia), allowing to determine a large pool of physiological markers, including those characterizing the functioning of the cardiovascular system and the vegetative balance of a person (Bocharin et al., 2021; Bocharin et al., 2022).

To assess the human cardiovascular system functioning, indicators characterizing the pumping function of the heart, the number of its contractions and peripheral vascular resistance are studied (Martusevich, 2022). In this assessment, the traditional use of ultrasound methods of heart examination is possible, but they are not always available to employees of non-medical organizations, and are also due to the time-consuming process of studying and the need for the presence of a specialized medical specialist.

In the protocol of a person's medical examination, generally accepted formulas are widely used to calculate hemodynamic parameters based on the input data of age, anthropometric indicators and blood pressure. For example, the Starr formula (Stair, 1954) is used to calculate shock volume, and the Poiseuille formula is used for total peripheral vascular resistance (Mehanna, et al., 2017). An alternative to this is the use of software and hardware complexes, such as MS FIT PRO 01, which also determines the above-mentioned markers of hemodynamics.

Due to the fact that in medical practice, the study of hemodynamic parameters in persons engaged in physical culture or sports, it is possible to use an instrumental method and a calculation method using formulas, there is a need to compare the reliability of the results obtained by the two methods. The accuracy and reproducibility of the research results are key factors in the measurement of hemodynamic parameters of the human body during mass examinations.

Research aim is to evaluate the reliability of the students' cardiovascular system hemodynamic parameters obtained by calculation using formulas and data obtained during testing using the MedicalSoft sports testing system.

Material & methods

100 students of the Volga Research Medical University aged 18.3 ± 1.2 years (Nizhny Novgorod, Russia) took part in the research project. All the young men agreed to the examination, which does not contradict the directive of the Helsinki Declaration of 2008. During the medical examination of all students participating in the experiment, they did not have any diseases and a medical group was established, without restrictions of PE classes. Systolic and diastolic blood pressure (mmHg) was determined tonometrically, using an automatic tonometer «Omron M2 Basic». The heart rate (beats per minute) was recorded using a tonometer and a MedicalSoft sports testing system.

The following hemodynamic indicators were used for the analysis: cardiac output of blood or stroke volume, ml and total peripheral vascular resistance of blood, $\text{din} \cdot \text{s} \cdot \text{cm}^{-5}$. These characteristics of the cardiovascular system were determined by manual calculation using the formulas of Starr (Stair, 1954) and Poiseuille (Mehanna, et al., 2017) and during testing in the middle of the day using a study of subjects on the MedicalSoft software and hardware complex. The reliability of the differences in the results of hemodynamic assessment by the two methods was obtained by constructing a Bland-Altman diagram (Bland, Altman, 1986), which represents a scattering diagram. The average value for two methods in one test is plotted along the X axis, and the difference in values in one test is plotted along the Y axis.

For statistical processing of the research results, the Statistica 10.1 and Excel for Windows software packages were used. The results are presented in the form of the mean value (M) and the standard deviation (σ). The absence of differences in the parameters obtained by different measurement methods was determined using the Student's parametric t-test.

Results

During the study, it was found that there are no statistically significant differences between different research models, $p > 0.05$ (Table 1).

Table 1. The students'hemodynamic parameters obtained by various measurement methods

Parameter	Formula (n=100)	MedicalSoft testing system (n=100)	p
Shock volume, ml	74.3 ± 6.1	75.8 ± 5.9	> 0.05
Total peripheral vascular resistance, $\text{din} \cdot \text{s} \cdot \text{cm}^{-5}$	1394.7 ± 85.4	1388.5 ± 84.7	> 0.05
Heart rate, bpm	75.6 ± 6.5	74.9 ± 6.3	> 0.05

To assess the consistency of the results obtained, Blend-Altman diagrams were constructed, in which the average of the measurement pair is displayed along the abscissa axis, and the absolute error is displayed along the ordinate axis. The average absolute error in the impact volume indicator was 3.9 ml (95% confidence interval from -5.3 ml to 2.6 ml). The maximum deviations of the obtained results do not exceed 0.7 ml, and negative values of the absolute error indicate that slightly large results are obtained when using a software and hardware complex in the process of measuring the impact volume (Figure 1).

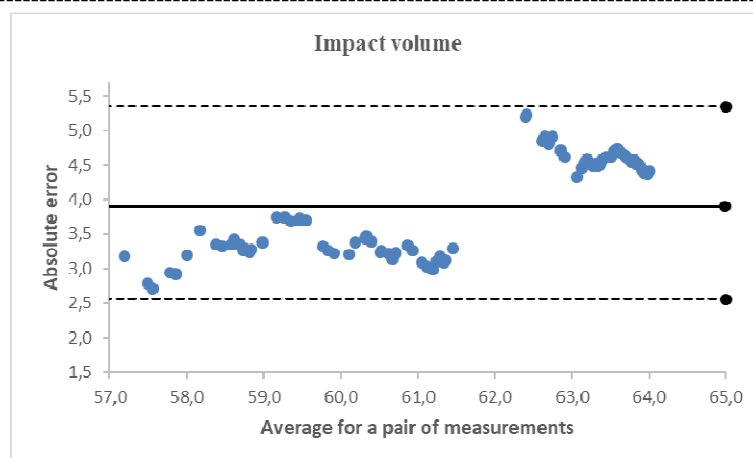


Fig. 1. The Blend-Altman diagram for absolute measurement errors of impact volume

At the same time, the absolute error for total peripheral vascular resistance (Figure 2A) was $-6.89 \text{ din} \cdot \text{s} \cdot \text{cm}^{-5}$ (95% confidence interval from $-8.6 \text{ din} \cdot \text{s} \cdot \text{cm}^{-5}$ to $-5.2 \text{ din} \cdot \text{s} \cdot \text{cm}^{-5}$). The expected maximum deviation when measured by the hardware complex will be no more than $0.9 \text{ din} \cdot \text{s} \cdot \text{cm}^{-5}$. For the heart rate parameter (Figure 2B), the average absolute error was determined at -0.4 beats/min (95% confidence interval from -0.65 beats/min to -0.14 beats/min), and the maximum deviation will not exceed 0.1 beats/min . For both parameters, by negative values of absolute errors, it is expected to visualize slightly smaller results when measured using a software and hardware complex in comparison with the tonometric method.

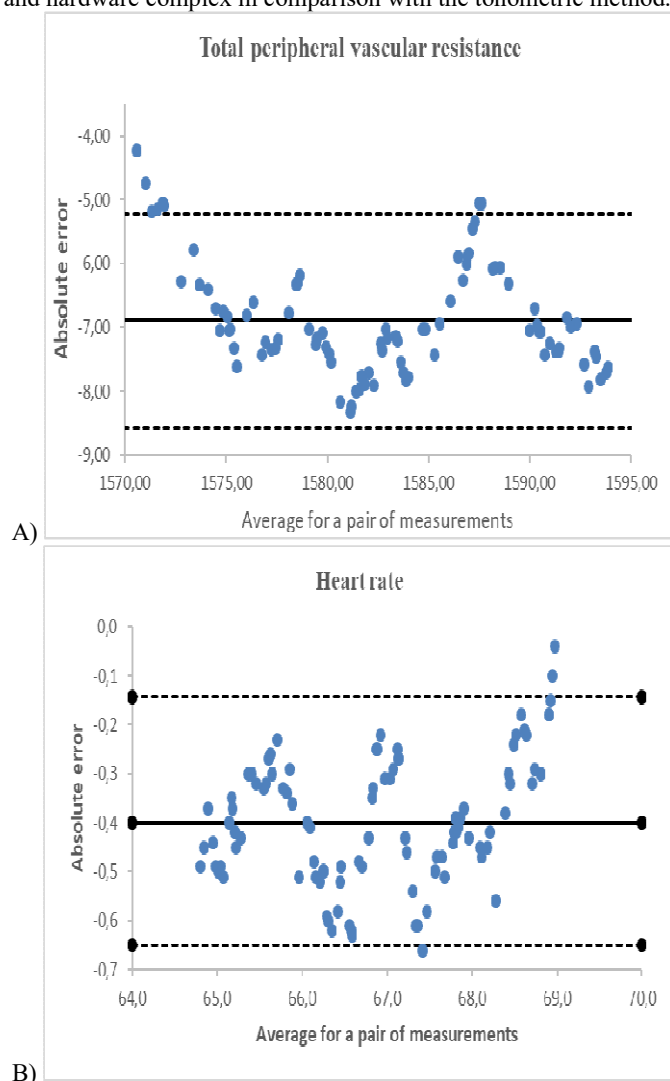


Fig. 2. Blend-Altman diagrams for absolute errors of total peripheral vascular resistance (A) and heart rate (B)

Based on the results obtained, almost all the values on the graphs are within the confidence limits, which gives grounds to consider the data obtained during measurement by the MedicalSoft software and hardware complex reliable, and this opens up opportunities for using this device during screening of systemic hemodynamics. In the absence of a Medical Soft software and hardware complex, traditional formulas can be used to calculate hemodynamic parameters.

Dicussion

The process of teaching young people in educational institutions is associated with high psycho-emotional and educational loads. Students often have a violation of work, rest and eating behavior, many have severe physical inactivity (Setiakarnawijaya et al., 2021; Kolokoltsev et al., 2021). These negative factors affect the hemodynamic parameters of the cardiovascular system and, in general, the human body (Misigoj-Durakovic et al., 2016). Therefore, constant and timely monitoring of the indicators of the cardiovascular system is necessary. This fact makes it possible to identify adaptive shifts in functional parameters and make adjustments to students' physical activity. Therefore, the choice of reliable hemodynamic tests for monitoring the cardiovascular system of a young organism seems to be a timely and urgent task in planning physical activity for students (Budzyn et al., 2018). This indicates the relevance of our research project.

Human body's functional systems adaptation to conditions of increasing physical exertion in order to maintain homeostasis of the main vital systems requires constant work of regulatory mechanisms, including hemodynamic characteristics (Bocharin et al., 2021; Bocharin et al., 2022; Tiwari et al., 2021; Young et al., 2018). Assessment of the body cardiovascular system activity is based on the choice of screening methods for systemic hemodynamics (Vanyushkin, 2016), including using traditional and modern instrumental measurement ones. The main condition of any method used to assess hemodynamics should be reliability and the ability to correlate with generally accepted methods for the study of physiological functions. Therefore, one of the main tasks of human hemodynamics research is a comparative study of the capabilities and results of new diagnostic complexes obtained when using them in comparison with conventional methods.

Our research has established that there are no significant differences between the calculated method of measuring the hemodynamic parameters of the students' body (heart stroke volume, total peripheral vascular resistance to blood flow) using the MedicalSoft hardware complex, which is confirmed by the results of the construction of the Blend-Altman diagram.

The results obtained by us indicate the possibility of effective use of these methods for screening hemodynamic parameters of the body. At the same time, minimal discrepancies were recorded when using the Blend-Altman method, which was used to determine the absolute errors values of two measurements with 95% confidence intervals, the average for a pair of measurements and the expected maximum deviation when using a hardware and software complex. This factor allows us to assert the expediency of using the device as the main method of studying the body hemodynamic parameters, as we reported earlier (Bocharin et al., 2021; Bocharin et al., 2022). In the absence of a Medical Soft sports testing system, it is possible to use computational methods for assessing human hemodynamics in research work.

Conclusions

The process of teaching young people in educational institutions is associated with high psycho-emotional and educational loads (Lopatina, 2022). Students often have a violation of work, rest and eating behavior (Romashov, & Kashparova, 2020), many have severe physical inactivity (Setiakarnawijaya et al., 2021; Kolokoltsev et al., 2021). These negative factors affect the hemodynamic parameters of the cardiovascular system and, in general, the human body (Misigoj-Durakovic et al., 2016). Therefore, constant and timely monitoring of the indicators of the cardiovascular system is necessary. This fact makes it possible to identify adaptive shifts in functional parameters and make adjustments to students' physical activity. Therefore, the choice of reliable hemodynamic tests for monitoring the cardiovascular system of a young organism seems to be a timely and urgent task in planning physical activity for students (Budzyn et al., 2018). This indicates the relevance of our research project.

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Conflicts of interest. The authors declare no conflict of interest.

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