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Comparative features of the morphometric correlates of blood pressure response to physical load of qualified athletes in some sports

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Abstract

Purpose: the purpose of this study was to establish morphometric parameters that correlate with the reactivity and recovery of blood pressure in response to a standard physical load in athletes of various game sports.

Material & Methods: to achieve the set goal, 101 qualified male athletes engaged in game sports were examined. All examined represented 3 game sports: 13 – water polo (average age 27.3±6.3 years), 59 – volleyball (average age 21.1±2.5 years), 29 – handball (average age 20.9±2.8 years). The morphometric study was carried out by traditional methods and included the determination of body length (BL, cm), body weight (BW, kg), chest circumference (CC, cm) with calculation of chest excursion (CE, cm), hand dynamometry, vital lung capacity (VLC, ml). Body mass index (BMI, $kg \times m^{-2}$), vital index (VI, $ml \times kg^{-1}$) and Erismann index (IE, c.u.) were calculated separately. The Martine test (20 squats in 30 seconds) was performed according to the traditional method.

Results: changes in SBP in response to load were the significantly greater in handball players compared to water polo players (p=0.025) and compared to volleyball players (p=0.022). Changes in SBP during 3 minutes of recovery are not related to morphometric parameters and obey the general mechanisms of changes in hemodynamic support under the influence of physical load. Changes in DBP during 3 minutes of recovery are related to chest circumference (CC, cm) and proportionality of its development (IE, c.u.) in volleyball and water polo players, and with BW (kg) in handball players. Changes in PBP during 3 minutes of recovery in handball players are not differentiated, in volleyball players they are related to the proportionality of chest development (IE, c.u.), and in water polo players to the BW (kg), CC (cm), mobility and proportionality of chest development (CE, cm and IE, c.u.).

Conclusions: the obtained results confirm that changes in DBP and PBP in response to physical load and during the recovery period after it are related to the morphometric parameters of the body, which can characterize the mechanisms of hemodynamic maintenance recovery and be useful in the selection and the organization of recovery measures in certain sports sport.

Key words: blood pressure, standart physical load, reaction, recovery, water polo, handball, volleyball.

Анотація

Порівняльні особливості морфометричних корелятів реакції артеріального тиску на фізичне навантаження у кваліфікованих спортсменів у деяких видах спорту. Мета:

встановлення морфометричних показників, що корелюють з реактивністю та відновленням АТ у відповідь на стандартне фізичне навантаження у спортсменів різних ігрових видів спорту. **Матеріал і методи:** для досягнення поставленої мети був обстежений 101 кваліфікований спортсмен-чоловік, що займаються ігровими видами спорту. Усі обстежені представляли 3 ігрові види спорту: 13 – водне поло (середній вік 27,3±6,3 року), 59 – волейбол (середній вік 21,1±2,5 року), 29 – гандбол (середній вік 20,9±2,8 року). Морфометричне дослідження, яке проводили традиційними методами, включало визначення довжини тіла (ДТ, см), маси тіла (МТ, кг), обводу грудної клітки (ОГК, см) з розрахунком екскурсії грудної клітки (ЕГ, см), динамометрії кисті, життєвої ємності легень (ЖЄЛ, мл). Окремо розраховували індекс маси тіла (ІМТ, кг×м$^{-2}$), життєвий індекс (ЖІ, мл×кг$^{-1}$) та індекс Ерісмана (ІЕ, у.о.). Тест Мартіне (20 присідань за 30 секунд) проводили за традиційною методикою. **Результати:** зміни САТ у відповідь на навантаження були достовірно більшими у гандболістів порівняно з ватерполістами (p=0,025) та порівняно з волейболістами (p=0,022). Зміни САТ протягом 3 хвилин відновлення не пов'язані з морфометричними показниками і підкоряються загальним механізмам змін гемодинамічного забезпечення під впливом фізичного навантаження. Зміни ДАТ протягом 3 хвилин відновлення пов'язані з окружністю грудної клітки (ОГК, см) і пропорційністю її розвитку (ІЕ, у.о.) у волейболістів і ватерполістів, а також з МТ (кг) у гандболістів. Зміни ПАТ протягом 3 хвилин відновлення у гандболістів не диференційовані, у волейболістів пов'язані з пропорційністю розвитку грудної клітки (ІЕ, у.о.), а у ватерполістів – з МТ (кг), ОГК (см), рухливістю і пропорційність розвитку грудної клітки (ЕГ, см та ІЕ, у.о.). **Висновки:** отримані результати підтверджують, що зміни ДАТ і ПАТ у відповідь на фізичне навантаження та в період відновлення після нього пов'язані з морфометричними параметрами організму, які можуть характеризувати механізми відновлення гемодинаміки та бути корисними при підборі та організації відновлювальних заходів у певних видах спорту.

Ключові слова: артеріальний тиск, нормативне фізичне навантаження, реакція, відновлення, водне поло, гандбол, волейбол.

Introduction

Monitoring blood pressure (BP) in athletes is one of the components of medical control in the conditions of a "sports heart" formation, which involves admission to physical exercises, forecasting the development of acute conditions during sports, their prevention, the making of individual programs for correcting the cardiovascular system functional state, as well as treatment and rehabilitation in case of the arterial hypertension clinical signs of various genesis (Berge et al., 2015; Sundstrom et al., 2011; Niebauer et al., 2018). High BP is considered as the most common abnormal finding during examinations of athletes (Sealy et al., 2010; De Matos et al., 2011; Leddy & Izzo, 2009; Corrado et al., 2008). At the same time, its prognostic value is completely unclear, and athletes with blood pressure of 160/100 mm Hg are allowed to continue exercising, if they do not have signs of end-organ damage, such as pathological left ventricular hypertrophy (Pelliccia et al., 2005; 2019), although the upper limit of blood pressure recommended by the European Society of Cardiology is 140/90 mm Hg. (Williams et al., 2018). On the other hand, hypertrophy of the myocardium of the left parts of the heart can be formed in athletes under the influence of both cyclic and acyclic training loads (Niebauer et al., 2018; Stewart et al., 2018). The latter contributes to an increase in the level of functional readiness of endurance athletes and may be crucial for the maintenance of hemodynamics in strength sports, albeit with different remodeling (Pelliccia et al., 2012). However, the presence of elevated blood pressure is a factor that can cause heart rhythm disturbances (Grimsmo et al., 2010), lead to vascular disasters. At the same time, it should be remembered that intense physical activity causes a significant increase in systolic blood pressure (SBP). According to authoritative research, the maximum values of SBP in highly qualified male athletes can reach 220 mm Hg or higher, especially in tall athletes (Caselli et al., 2016). At the same time, diastolic blood pressure (DBP) fluctuates slightly and remains within the initial values (Caselli et al., 2016). Despite the fact that there is a relationship between the intensity of physical exertion and the change in SBP, there are no approaches to standardizing tests with physical exertion to determine the tolerance of the blood pressure support system. There are isolated attempts to unify the assessment based on the definition of prognostically possible blood pressure values, taking into account gender, age, initial values of blood pressure, power of physical exertion (Szmigielska et al., 2016; Mascherini et al., 2022; Zambolin et al., 2022). This is due to several factors. First, blood pressure measurement is discrete, because most doctors use methods based on the Korotkov method (Parati et al., 2021). Therefore, to obtain significant data at rest, it is recommended to measure blood pressure three times on two arms (Stergiou et al., 2022). In addition, there is a variability of BP at each heart contraction, which is related to the respiratory cycle and depends on the state of the body (Abreu et al., 2022; Eckberg, 2009; Guzii et al., 2021; Papaioannou et al., 2020). Secondly, there are many external factors that affect the measurement results, which are not always possible to level in the conditions of operational and current control (Berge et al., 2015), and blood pressure significantly reacts to the psycho-emotional component of a person's state, etc. (Parati et al., 2021; O'Brien et al., 2013). Therefore, the search for measurement methods and their standardization is currently ongoing, and the prognostic value

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of blood pressure in athletes remains incompletely defined (Caselli et al., 2016; Berge et al., 2015).

In the practice of sports medicine, tests with physical load, the purpose of which is to determine the body's tolerance to physical work, have become widespread – the so-called cardiopulmonary testing (Bourdon et al., 2017; Romanchuk & Guzii, 2020; Abreu et al., 2022). However, BP changes during its execution are taken into account in a discrete mode and have a limited diagnostic value (Bourdon et al., 2017; Caselli et al., 2016). Only in recent years, the technological possibilities of registering blood pressure at each heart contraction have appeared, which significantly adds information for analysis and the search for new diagnostic criteria (Karemaker & Wesseling, 2008; Stergiou et al., 2020; Kishi, 2018; Guzii et al., 2021; Papaioannou et al., 2020; Zambolin et al., 2022).

The well-known qualitative tests are the ones with a standard physical load, which involve the registration of blood pressure indicators in order to determine the type of reaction of the cardiovascular system to a standard physical load (Szmigielska et al., 2016; Zanevskyy et al., 2017). Such tests include: the Martine test (20 squats in 30 seconds), the Kotov-Deshin test (a 3-minute run in place at a pace of 180 steps/min), a test with a 15-second run in place at a maximum pace, a test Levi-Horynevska (60 jumps in 30 seconds), Letunov's three-moment test, Kverg's four-moment test, etc. (Abramov et al., 2014) Their use allows doctors of sports medicine during screening examinations to clarify the data that testify to the possibility of performing physical exercises by athletes of all levels of sports skill and characterize the types of reactions of the cardiovascular system, which are based on changes in heart rate and blood pressure. The Martine test is most often used in the practice of screening examinations.

Observations of highly qualified athletes made it possible to note that the reactivity of the body of athletes of various sports to standard physical exertion varies significantly and does not always fit into the above-defined ranges of changes in the indicators of the cardiovascular system, even within sports of the same orientation, level of functional readiness, etc. (Szmigielska et al., 2016). It is appropriate to mention the results that showed that changes in blood pressure in athletes have a significant dependence on such morphometric parameters as the component composition of the body, primarily its lean mass and fat tissue content (Durmic et al., 2017). In this regard, the known data on the relationship between BP and body length (BL, cm) are also indicative (Clarke et al., 2021).

The purpose of this study was to establish morphometric parameters that correlate with the reactivity and recovery of blood pressure in response to a standard physical load in athletes of various game sports.

Material and methods of research

Participants

To achieve the set goal, 101 qualified male athletes engaged in game sports were examined. All examined represented 3 game sports: 13 – water polo (average age 27.3±6.3 years), 59 – volleyball (average age 21.1±2.5 years), 29 – handball (average age 20.9±2.8 years). All the athletes represented the masters clubs of the championships of Ukraine. Examinations were carried out in the morning hours on an empty stomach at the beginning of the preparatory period of the annual training cycle using standard research methods on the basis of the Lviv medical and physical culture dispensary in 2013-2014.

Methods

The morphometric study was carried out by traditional methods and included the determination of body length (BL, cm), body weight (BW, kg), chest circumference (CC, cm) during inhalation, exhalation and pause with calculation of chest excursion (CE, cm), hand dynamometry, vital lung capacity (VLC, ml). Body mass index (BMI, kg×m^{-2}), vital index (VI, ml×kg^{-1}) and Erismann index (IE, c.u.) were calculated separately (Abramov et al., 2014).

HR was counting at the radial artery, during 10 seconds, palpatory. Blood pressure was recorded in a sitting position on the left arm, using a mercury sphygmomanometer, with an accuracy of 2 mm Hg.

Procedure

The Martine test (20 squats in 30 seconds) was performed according to the traditional method with the determination of heart rate (HR, min^{-1}), systolic blood pressure (SBP, mmHg) and diastolic blood pressure (DBP, mmHg) with calculation of pulse BP (PBP, mmHg) in the initial state, as well as in the first, second and third minutes of recovery. At the same time, the HR during the recovery period was determined in the first and last 10 s of each of the three minutes after the end of the load in the sitting position (Fig. 1). In order to analyze the dynamics of changes in all mentioned indicators in athletes, their increments were determined in comparison with the initial state: ΔHRload (%), ΔHRrec (%) –

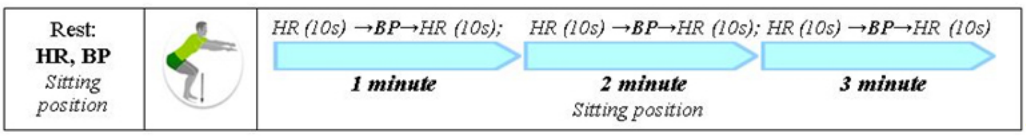

Fig. 1. Scheme of the Martine test.

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respectively for HR immediately after exercise and HR at the end of the third minute of recovery. Similarly, the following were determined: ΔSBPload (%), ΔSBPrec (%), ΔDBPload (%), ΔDBPrec (%), ΔPBPload (%), ΔPBPrec (%).

Statistical analysis

Statistical data analysis was carried out by non-parametric methods using the Statistica 10.0 program. The probability of differences was determined using the Mann-Whitney test, correlations – using the Spearman method.

Results of the study

Table 1 presents the results of calculating the average values of the main parameters of the examined athletes' physical development. Significant differences between the physical developments of the athletes of the studied game sports were noted only when comparing volleyball and handball players with water polo players. They related to differences in BW (kg), BMI (kg×m^{-2}), CC (cm) in pause, hand dynamometry (kg), VLC (ml), Erisman index, which were significantly greater in the latter. First of all, they witnessed the development of the chest, absolute values of strength, and a greater, probably due to the content of muscle and fat tissue, body weight, as well as a strong physique, characteristic of this type of sport. Probably, these differences were also related to the break in the educational and training process, which is longer for water polo players. First of all, this concerns the increase in BW and its fat component. There were no significant differences in physical development indicators between volleyball players and handball players.

In the table 2 presents comparative data of indicators of the cardiovascular system activity in the initial state. Slightly, but significantly higher values of SBP (mm Hg) and DBP (mm Hg) indicators in water polo players compared to volleyball and handball players are worthy of attention. For SBP 120.0 (120.0; 130.0) vs. 117.5 (110.0; 120.0), $p<0.001$, and vs. 115.0 (110.0; 120.0), $p<0.01$, respectively; for DBP 75.0 (75.0; 80.0) vs. 70.0 (70.0; 75.0), $p<0.01$, and vs. 70.0 (70.0; 80.0), $p<0.01$, respectively.

Probably, such an increase in the average values of SBP and DBP is more related to age, BW (kg) and features of the educational and training process of water polo players, which is more aimed at developing strength abilities. The latter is possible and determines the peculiarities of the vegetative and baroreflex maintenance of the hemodynamics of water polo players, which was shown in previous studies (Guzii & Romanchuk, 2017).

In fig. 2 presents graphs of average changes in HR (min^{-1}), SBP (mm Hg) and DBP (mm Hg) in response to a standard load. Fig. 2a shows that the average changes in HR in response and during the recovery period after a standard load in athletes of all studied sports do not differ significantly, in contrast to SBP (Fig. 2b), DBP (Fig. 2c) and PBP (Fig. 2d).

The curves of changes in SBP (mmHg) and DBP (mmHg) have a similar appearance. However, there

Table 1. Average parameters of athletes' physical development of various game sports, M (25; 75)

Parameter	Water polo n=13	Volleyball n=59	Handball n=29
BW, kg	96.0 (84.5; 99.0)	76.0 (69.0; 86.0)***	79.5 (71.0; 86.0)***
BL, cm	182.5 (181.0; 190.0)	186.0 (179.0; 194.0)	183.0 (181.0; 187.0)
BMI, kg×m^{-2}	27.6 (25.6; 29.9)	22.5 (20.9; 23.7)***	23.6 (20.8; 25.1)***
Body square, m^2	2.15 (2.06; 2.27)	2.00 (1.87; 2.16)	2.01 (1.93; 2.11)
Chest Circumference, pause, cm	106.0 (100.0; 111.0)	96.0 (91.0; 100.0)***	95.0 (91.0; 99.0)***
Chest Exursion, cm	14.0 (12.0; 15.0)	14.0 (12.0; 15.0)	13.0 (13.0; 14.0)
Dynamometry, rights, kg	52.0 (44.0; 60.0)	41.0 (35.0; 50.0)**	44.5 (40.0; 49.0)**
Dynamometry, left, kg	50.0 (42.0; 58.0)	40.0 (34.0; 49.0)**	42.0 (39.0; 48.0)**
VLC, ml	5450 (5100; 6150)	5000 (4500; 5500)*	4800 (4500; 5200)**
VI, ml×kg^{-1}	59.5 (55.2; 65.6)	63.3 (57.4; 69.8)	56.6 (39.2; 67.1)
Erisman index, c.u.	11.5 (10.3; 20.0)	1.8 (–2.0; 7.5)***	2.3 (–0.8; 5.5)***
Pinier index, c.u.	–6.5 (–25.5; –4.0)	16.5 (4.5; 25.0)***	10.0 (1.5; 24.0)***

* – $p<0.05$, ** – $p<0.01$, *** – $p<0.001$, comparition with water polo.

Table 2. Average parameters of athletes' cardiovascular system activity in the initial state, M (25; 75)

Параметр	Water polo (WP) n=13	Volleyball (V) n=59	Handball (H) n=29
HR, min^{-1}	72.0 (66.0; 72.0)	72.0 (66.0; 72.0)	72.0 (66.0; 72.0)
SBP, mmHg	120.0 (120.0; 130.0)	117.5 (110.0; 120.0)***	115.0 (110.0; 120.0)**
DBP, mmHg	75.0 (75.0; 80.0)	70.0 (70.0; 75.0)**	70.0 (70.0; 80.0)**
PBP, mmHg	45.0 (40.0; 50.0)	40.0 (40.0; 50.0)	40.0 (40.0; 50.0)

* – $p <0.05$, ** – $p <0.01$, *** – $p <0.001$, comparition with water polo.

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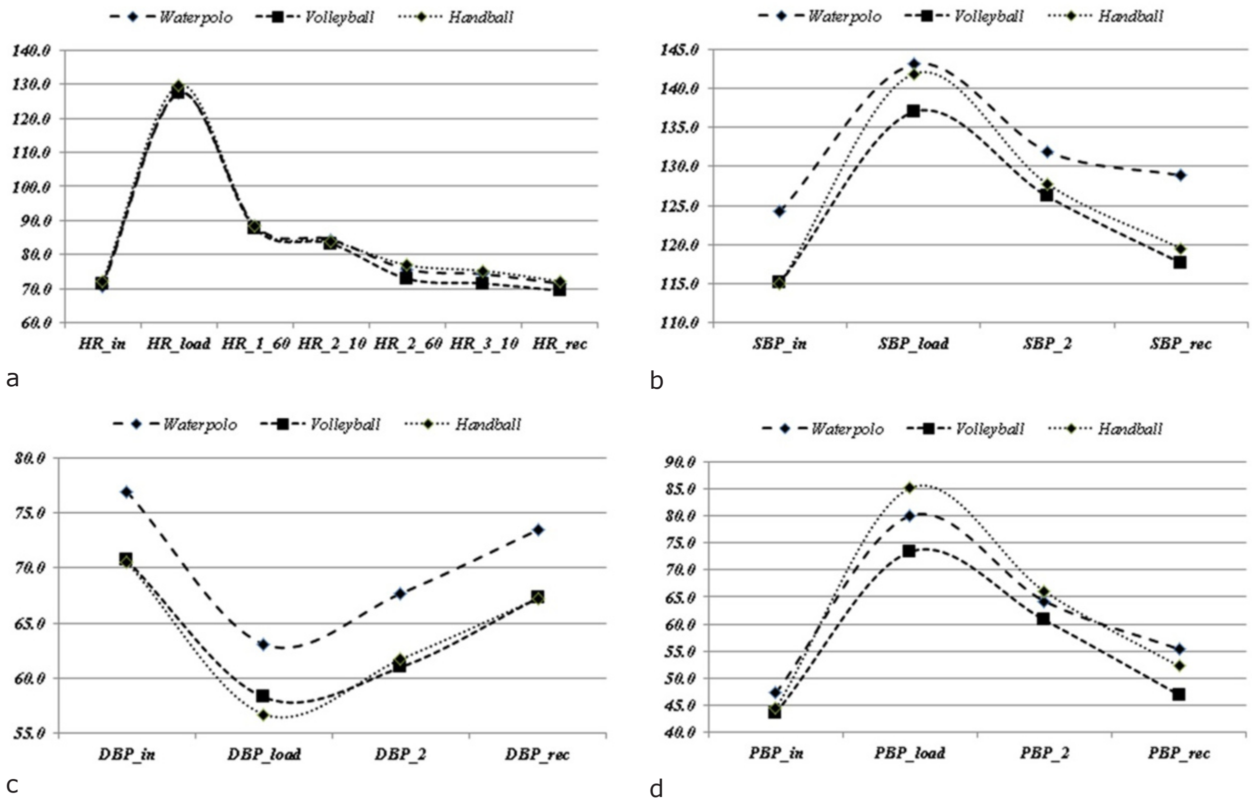

Fig. 2. Graphs of changes in average indicators of HR (a), SBP (b), DBP (c) and PBP (d) in game sports athletes during performing the Martine test.

Table 3. Average parameters of the increase in indicators of the athletes cardiovascular system immediately and at the end of the third minute of recovery after a standard load, %, M (25; 75)

Parameter	Water polo (WP)	Volleyball (V)	Handball (H)	p		
				WP-V	WP-H	V-H
ΔHRload, %	83.3 (66.7; 100.0)	83.3 (69.2; 100.0)	83.3 (71.4; 91.7)	0.703	0.915	0.503
ΔSBPload, %	16.7 (12.0; 17.4)	16.7 (16.7; 20.0)	20.0 (16.7; 27.3)	0.061	**0.025**	**0.022**
ΔDBPload, %	–20.0 (–20.0; –14.3)	–23.1 (–28.6; –12.5)	–16.7 (–28.6; –14.3)	0.895	0.805	0.633
ΔPBPload, %	75.0 (66.7; 87.5)	80.0 (50.0; 100.0)	98.0 (66.7; 125.0)	0.445	0.073	0.062
ΔHRrec, %	0.0 (0.0; 0.0)	0.0 (0.0; 8.3)	0.0 (–7.1; 0.0)	0.841	0.734	0.712
ΔSBPrec, %	4.0 (0.0; 4.2)	0.0 (0.0; 0.0)	0.0 (0.0; 8.3)	0.283	0.840	0.101
ΔDBPrec, %	–5.9 (–6.7; 0.0)	0.0 (–7.7; 0.0)	0.0 (–12.5; 0.0)	0.927	0.980	0.878
ΔPBPrec, %	11.1 (10.0; 25.0)	0.0 (0.0; 20.0)	20.0 (0.0; 25.0)	0.482	0.906	0.258

are certain differences. First, attention is drawn to a more pronounced increase in SBP (mmHg) in comparison with the initial state in handball players (Fig. 2b) in response to a standard load, which is accompanied by a more pronounced decrease in DBP (mmHg) (Fig. 2c).

Secondly, changes in SBP (mmHg) and DBP (mmHg) in water polo players occurred at a higher level associated with the initial values of these parameters, although they resembled the dynamics of volleyball and handball players. To analyze the data, we decided to use relative values that characterized the increase in HR (min^{-1}), SBP (mmHg), DBP (mmHg) and PBP (mmHg) in percentage (%) in relation to to the original data. That is, a number of indicators characterized the increase in indicators in response to the load, and a number – the return of indicators to the initial values. The analysis of these indicators is presented in table. 3.

According to the obtained data, it can be stated that among all the indicators, the differences in the indicators of SBP increase (ΔSBPload, %) in response to a standard load were found only in handball players compared to water polo players 20.0 (16.7; 27.3) versus 16.7 (12.0; 17.4), p=0.025, and to volleyball players 20.0 (16.7; 27.3) versus 16.7 (16.7; 20.0), p=0.022, which confirmed the visual assessment (Fig. 2b).

At the trend level, there were differences in PBP up (mmHg) in handball players compared to water polo players 98.0 (66.7; 125.0) versus 75.0 (66.7; 87.5), p=0.073, and volleyball players 98.0 (66.7; 125.0) against 80.0 (50.0; 100.0), p=0.062. According to the indicators of recovery of HR and BP, no significant differences were registered.

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At the next stage of the research, in order to achieve the goal of our work, Spearman's correlation analysis was conducted between indicators of increases in HR and BP parameters in response to a standard load and in the third minute of recovery after it with the indicators of the physical development. In this version of the analysis, it was possible to establish which of the morphometric parameters are associated with the response of HR and BP to a standard load and which are associated with its recovery.

Some of the indicators of physical development had no relationship with changes in indicators of the cardiovascular system. Among them there are BMI (kg×m^{-2}) and hand dynamometry (kg). The IE indicator (c.u.), which characterizes the proportionality of the thoracic cage development as well as the indicators of CC (cm) and BW (kg) had the most connections with changes in HR and BP. Among the other morphometric indicators which had one or more connections were BL (cm), CE (cm), VLC (ml), VI (ml×kg^{-1}).

Analyzing the changes in HR and BP in response to exercise in representatives of the investigated game sports (Table 4), it should be noted that the heart rate response in volleyball players (ΔHRload, %) is inversely related to VI (ml×kg^{-1}), $r=-0.674$, $p<0.05$, and in handball and water polo players, HR changes are not connective with morphometric indicators at all. At the same time, changes in DBP (mm Hg) and PBP (mmHg) in response to exercise in handball and water polo players are in a certain way related to parameters of physical development. Decrease in DBP (ΔDBPload, %) in handball players is weakly inversely related to BW (kg) and BL (cm), $r=-0.371$, $p<0.05$, and $r=-0.377$, $p<0.05$, respectively, and for water polo players, it is moderately inversely – with IE (c.u.), $r=-0.623$, $p<0.05$. That is, the reduction of DBP in response to a given standard load in handball players with greater BW and greater BL is more pronounced, and in water polo players it is determined by the chest proportionality (the wider the chest, the greater the reduction in DBP). Relations with the increase in PBP (ΔPBPload, %) are somewhat different. In handball players, it is weakly inversely related to VLC (ml), $r=-0.424$, $p<0.05$, and in water polo players, it has a direct moderate relationship with BW (kg), CC (cm) and IE (c.u.), $r=0.614$, $p<0.05$, $r=0.654$, $p<0.05$, and $r=0.682$, $p<0.05$, respectively. That is, in handball players, the larger the VLC (ml), the smaller the increase in PBP (mm Hg), and in water polo players, the larger the BW (kg), CC (cm), IE (c.u.), the increase in PBP (mmHg) is more significant. It is logical that in handball players, the increase in PBP (mmHg), which is directly related to the heart stroke volume, is smaller in conditions of better oxygen supply to the body, the reserve of which is determined by the VLC (ml). On the other hand, in water polo players, the demand for oxygen supply is greater due to the better development of muscle tissue, and an increase in the stroke volume of the heart allows you to compensate for this demand in conditions of a wider chest than in other athletes and as the same as in other athletes the CE (cm).

Analyzing the relationship between athletes indicators of the cardiovascular system recovery and the morphometric parameters (Table 5), it should be noted that the indicators of IE (c.u.), CC (cm) and BW (kg) had the most connections. At the same time, it should be noted that the athletes of the studied sports did not differ in terms of indicators of the cardiovascular system recovery (Table 3). Among the morphometric parameters, the indicator that was associated with HR recovery (ΔHRrec, %) after exercise was the BL indicator (cm) in volleyball players, $r=-0.604$, $p<0.05$, which characterized faster recovery in taller athletes. In athletes of other sports, none of the studied morphometric parameters determined HR recovery. Also, none of them was associated with the recovery of SBP (ΔSBPrec, %). On the other hand, the morphometric parameters were significantly related to the recovery of diastolic (ΔDBPrec, %) and pulse pressure (ΔPBPrec, %) indicators. Thus, in volleyball and water polo players, the recovery of DBP was associated with CC (cm), $r=-0.761$, $p<0.05$, and $r=-0.631$, $p<0.05$, respectively, and with IE (c.u.), $r=-0.766$, $p<0.05$, and $r=-0.749$, $p<0.05$, respectively. Taking into account the significant differences of these indicators in athletes of these sports (Table 1), it can be assumed that such dependencies of DBP dynamics are determined not so much by the size or proportionality of the chest,

Table 4. Significant ($p<0.05$) correlations of indicators of the cardiovascular system reaction with indicators of athletes physical development

Parameter	Water polo		Volleyball	Handball	
	ΔDBPload, %	ΔPBPload, %	ΔHRload, %	ΔDBPload, %	ΔPBPload, %
BM, kg		**0.614**		**–0.371**	
BL, cm				**–0.377**	
CC, cm		**0.654**			
CE, cm					
IE, c.u.	**–0.623**	**0.682**			
VLC, ml					**–0.424**
VI, ml×kg^{-1}			**–0.674**		

Table 5. Significant (p<0.05) correlations of indicators of the cardiovascular system recovery with indicators of athletes physical development

Parameter	Water polo			Volleyball		Handball
	ΔDBPrec, %	ΔPBPrec, %	ΔHRrec, %	ΔDBPrec, %	ΔPBPrec, %	ΔDBPrec, %
BM, kg	**–0.703**	**0.763**				**–0.466**
BL, cm			**–0.604**			
CC, cm	**–0.631**	**0.749**		**–0.761**		
CE, cm		**0.655**				
IE, c.u.	**–0.749**	**0.736**		**–0.766**	**0.652**	
VLC, ml						
VI, ml×kg^{-1}						

but by the characteristic mechanisms of the suction function of the chest, which indirectly affect the level of DBP (Romanchuk, 2022). At the same time, in handball players, the size and proportionality of the chest is not significantly different from volleyball players, but significantly different from water polo players (Table 1). In handball and water polo players, there is a relationship between DBP recovery and BW (kg) r=–0.466, p<0.05, and r=–0.703, p<0.05, which proves better DBP recovery in athletes with greater BW (kg). This is probably due to the greater participation of the BW muscle component, which in these game sports develops more actively in the educational and training process due to strength-oriented training.

Recovery of PBP by relative values (ΔPBPrec, %) in athletes of the studied game sports did not differ (Table 3) and showed a certain tendency to its increase at the end of the 3rd minute of recovery in comparison with the initial values in the range of 0-25% in all sports. In handball players, this indicator of hemodynamics was in no way related to the physical development parameters. In volleyball players, the indicator ΔPBPrec (%) had a directly proportional dependence with IE (c.u.), r=0.652, p<0.05, which allows us to associate a slower recovery of PBP with a wider chest, and in water polo players, in addition to IE (c.u.), r=0.736, p<0.05, slower recovery of PBP was determined by BW (kg), r=0.763, p<0.05, CC (cm), r=0.749, p<0.05, and CE (cm), r=0.655, p<0.05. That is, in these game sports, there is a significant dependence of PBP recovery to initial values on the structure and mobility of the chest. The most likely factor, especially among water polo players, is the activation during the recovery period of the usual response mechanisms associated with performing loads in a horizontal position in the water, which is realized through the activation of respiratory muscles to ensure the return of blood and it's characterized by a slowdown in the recovery of DBP and PBP to initial values, taking into account larger absolute values in begin.

Discussion

At the beginning of the obtained data discussion, attention should be paid to the fact that water polo players significantly differed from volleyball and handball players in terms of their morphometric data (Table 1). First of all, they have the more significant development of the chest, strength abilities and body strength. Among the initial data of the cardiovascular system, their significantly higher values of SBP (mm Hg) and DBP (mm Hg) were also noteworthy. Such differences of water polo players in the initial state may be related to older age, greater body weight and the duration of the break in the educational and training process, because the research was conducted at the beginning of the preparatory period. At the same time, the analysis of changes in HR (min^{-1}), SBP (mm Hg), DBP (mm Hg) and PBP (mm Hg) indicators in response to a standard load (20 squats) in qualified volleyball players, of handball and water polo players showed that according to average changes in HR (min^{-1}) and its increase ΔHRload (%) no significant differences are noted; according to changes in SBP (mm Hg) and its increase ΔSBPload (%) a more significant increase is noted in handball players; the latter against the background of the same changes in PBP (mm Hg) and its increase in ΔPBPload (%) in handball players is accompanied by a tendency to a more significant increase in PBP (mmHg) and its increase in ΔPBPload (%). It was also informative that during the recovery period after a standard load, none of the dynamics of changes in cardiovascular system indicators (ΔHRrec, %; ΔSBPrec, %; ΔDBPrec, %; ΔPBPrec, %) in athletes of various game sports did not stand out. That is, the average values of changes in the indicators of the cardiovascular system in the athletes of the studied game sports showed a normotensive and an excellent type of reaction to standard physical exercise.

The analysis of the correlations of the specified indicators with the athletes' physical development parameters made it possible to determine certain dependencies that can characterize the peculiarities of the response and recovery of HR and BP, taking into account individual morphometric parameters, which can be determined by the specifics of the educational and training process and game activities of the athletes of the studied sports, their readiness level and basic morphometric parameters.

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Only in volleyball players, the cardiovascular system response to the load according to indicators of the chronotropic response (ΔHRload, %) had an inverse relationship with the VI (ml×kg^{-1}), which is probably explained by the greater of the chronotropic response of the heart in conditions of lower values of the relative reserves of oxygen supply, which depend on VI (ml×kg^{-1}). Moreover, such a connection was not observed among athletes who played other types of sports. The growth of SBP (ΔSBPload, %) in none of the game sports did not depend on morphometric parameters. Certain differences in relations with morphometric parameters were noted in indicators characterizing changes in vascular tone (ΔDBPload, %) and pumping function of the heart (ΔPBPload, %), among handball and water polo players, in the absence of such changes among volleyball players. First of all, the dependence of the decrease in DBP (mmHg) on BW (kg) and BL (cm) against the background of the dependence of the increase in PBP (mmHg) on VLC (ml) in handball players, and the dependence of the decrease in DBP (mmHg) from the proportionality of the chest (IE, c.u.) against the background of the dependence of the PBP increase (mmHg) on BW (kg), CC (cm) and IE (c.u.) in water polo players. That is, in volleyball players, the reaction of blood pressure indicators is in no way related to morphometric parameters; the decrease in vascular tone in handball players there is determined by BW and BL, and in waterpolo players by the chest proportionality. An increase in the pumping function of the heart in handball players is inversely related to the reserve capabilities of the respiratory system, and in water polo players with BW and the formation of a wider chest skeleton. The most likely cause of such dependencies is the peculiarities of the formation of biomechanical relationships, which determine the formation of motor skills characteristic of various game sports. That is, the dependence of morphometric indicators and changes in DBP and PBP indicators make it possible to assume that the functional activity of the diaphragm is of significant importance among water polo players, which in the conditions of the water environment plays a decisive role in the hemodynamic system adaptative reactions in response to load.

During the recovery period, the indicators of the return of the parameters of the cardiovascular system did not differ among athletes of all the studied sports. Only in volleyball players, HR recovery was associated with morphometric parameters and occurred faster in tall athletes. As well as in response to exercise, during the first three minutes of recovery, indicators of SBP reduction (ΔSBPrec, %) did not depend on morphometric parameters in all groups of athletes. The latter allows us to assume that the recovery of the SBP after exercise obeys the general mechanisms of hemodynamic reduction in athletes of the studied sports, not related to the defined morphometric parameters.

Differences in the relationships of morphometric parameters with the recovery of DBP (ΔDBPrec, %) and PBP (ΔPBPrec, %) in athletes of the studied game sports allow us to assume the involvement of various mechanisms of returning DBP and PBP to the initial values associated with the features of the body structure and educational training process of athletes. It is also appropriate to continue research to understand the relationship between changes in DBP and PBP with the parameters of the chest structure, which ensure the functioning of the respiratory system and determine its relationship with the variability of the cardiovascular system function, including heart and blood pressure (Guzii et al., 2018; 2019; 2020; 2021). In any case, the obtained results can be useful in determining the means of recovery after training and competitive loads, which have a direct effect on the mechanisms of maintaining vascular tone and return of venous blood, in game sports athletes.

Conclusion

The study of the relationship between the morphometric parameters of volleyball, handball and water polo athletes and the dynamics of changes in blood pressure indicators in response to and after standard physical load (20 squats) made it possible to establish that:

1) Changes in SBP in response to load (ΔSBPload, %) are significantly greater in handball players compared to water polo players (p=0.025) and compared to volleyball players (p=0.022).

2) Changes in DBP and PBP in response to load (ΔDBPload, % and ΔPBPload, %) and during 3 minutes of recovery in athletes of the studied game sports are not significantly differentiated.

3) Changes in SBP during 3 minutes of recovery (ΔSBPrec, %) are not related to morphometric parameters and obey the general mechanisms of changes in hemodynamic support under the influence of physical load;

4) Changes in DBP in response to load (ΔDBPload, %) are associated with weight and height indicators in handball players and with the proportionality of chest development in water polo players;

5) Changes in DBP during 3 minutes of recovery (ΔDBPrec, %) are related to chest circumference (CC, cm) and proportionality of its development (IE, c.u.) in volleyball and water polo players, and with BW (kg) in handball players;

6) Changes in PBP in response to load (ΔPBPload, %) in handball players are associated with VLC (ml), and in water polo players with BW (kg) circumference and proportionality of chest development (CC, cm, IE, c.u.);

7) Changes in PBP during 3 minutes of recovery (ΔPBPrec, %) in handball players are not differentiated, in volleyball players they are related to the proportionality of chest development (IE, c.u.),

and in water polo players to the BW (kg), CC (cm), mobility and proportionality of chest development (CE, cm and IE, c.u.).

8) The obtained results confirm that changes in DBP and PBP in response to physical load and during the recovery period after it are related to the morphometric parameters of the body, which can characterize the mechanisms of hemodynamic maintenance recovery and be useful in the selection and the organization of recovery measures in certain sports sport.

Author's contribution

Conceptualization, O.G. and O.R.; methodology, O.G., S.S. and O.R.; software, O.G. and O.R.; check, O.G. and O.R.; formal analysis, O.R.; investigation, O.G. and S.S.; resources, O.G., O.R. and M.O.; data curation, O.R.; writing – rough preparation, O.G. and O.R.; writing – review and editing, O.G. and O.R.; visualization, O.R.; supervision, A.M.; project administration, O.G. and O.R. All authors have read and agreed with the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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