Features of the hemodynamic state in female athletes with disabilities

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Abstract
Objective of the study was to identify the features of the hemodynamic state and aerobic performance of athletes with disabilities to optimize the training process.
Methods and structure of the study. Hemodynamic parameters and the results of stress testing were studied in athletes with disabilities involved in cyclic sports (skiing, athletics, swimming and orienteering (n=59). All data obtained were further compared with similar indicators of healthy female racers (n =89).
Results and conclusions. It was revealed that, despite the fact that a decrease in resting heart rate determines the physiological adaptation of the cardiosystem to regular training in endurance sports, no significant differences in heart rate in the orthotest were found in the groups of examined female athletes. When analyzing the functional state of athletes, it is advisable to take into account the parameters of the hemodynamic state, especially in the vertical position of the body. For the full development of the sports potential of athletes with disabilities, stage-by-stage comprehensive control in the training process and its individualization are necessary.

Keywords: *hemodynamic monitoring, athletes, cyclic sports, health limitations, hemodynamic condition*

Introduction. Success in sports depends on many factors, including the body's reserves and the state of life-support systems [1, 2]. Moreover, the cardio-respiratory system, in the context of sports at all levels of training and in various sports specializations, is one of the leading ones and determines the achievement of high sports results. Considering the fact that adaptive sports is one of the important directions in the development of the sports movement in the world, understanding the characteristics of the internal state of athletes with disabilities will allow us to determine the direction of the training process and the realization of the sports potential of this group of people. Hemodynamic monitoring is one of the informative and accessible methods for assessing the functional state of the cardiorespiratory system, manifestations of its adaptation to training loads in order to timely adjust the training process.

Objective of the study was to identify the features of the hemodynamic state and aerobic performance of athletes with disabilities to optimize the training process.

Методика и организация исследования. The scientific work was carried out on the basis of the laboratory of "Functional testing and comprehensive control in sports" of the Institute of Physical Culture and Medicine of UrFU. The hemodynamic state was assessed in an active orthotest using the monitor of a resuscitator-anesthesiologist MARG-10-01 (Microlux, Russia) and veloergospirometry using a FitmatePRO metabolograph (COSMED, Italy) and a stress testing system SHILLER AG (Switzerland) according to the maximum test protocol with continuously increasing load. The study involved 59 athletes with disabilities involved in cyclic sports (cross-country skiing, athletics, swimming and orienteering), as well as 89 healthy female racers. Both groups of athletes were divided into the same age subgroups, while all the girls successfully performed at official regional competitions in selected sports and had age-appropriate training experience. The group of athletes with disabilities consisted of individuals with varying degrees of severity of hearing and vision impairment. Anthropometric data of groups of female athletes are presented in table 1.

Table 1. Anthropometric data of female athletes of the study groups

Age	Groups	Number, persons	Weight, kg	Growth, cm	BMI, kg/m²
11-12	Disabilities	16	44,65±5,33 (38,2–52,8)	154,42±5,39 (146–162,5)	18,67±1,2 (17,2–20)
	Female skiers	12	42,57±8,39 (33–54,1)	154,29±6,95 (143–162,5)	17,9±2,21 (16,2–21)
13-14	Disabilities	14	56,15±6,81 (46,9–62,2)*	164,5±8,58 (155–174)*	21,6±2,01 (19,5–23,5)*
	Female skiers	26	56,05±8,47 (42–72)**	167,04±7,13 (156,5–180)**	20,3±1,97 (18,1–23,8)*
15-17	Disabilities	14	49,63±10,19 (38,4–63,1)	162,5±10,85 (147–170)	19,4±2,12 (17,8–21,8)
	Female skiers	36	59,17±6,88 (47,1–68)	168,36±8,21 (154–177,5)	20,73±1,77 (17,3–22,6)
18-20	Disabilities	15	55,12±9,07 (44–64,8)	166,8±6,14 (159–174)	19,7±1,88 (17,4–21,7)
	Female skiers	15	57,97±5,73 (45–69)	168,18±4,14 (162–175)	20,96±1,09 (19,6–22,9)

**differences are significant (p<0,05) between the marked group and the previous age group*
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In the process of hemodynamic monitoring in an active orthotest using the rheovasography method with synchronous ECG recording, indicators such as heart rate (HR, beats/min), stroke volume (SV, ml), end-diastolic volume (EDV, ml), and of course -diastolic index (CDI, ml/m2) in the supine and standing position [3]. Since SV and EDV are proportionally related to each other by the ejection fraction, and also to level the anthropometric indicators of athletes, the relative EDV, equal to the ratio of EDV to body surface area, was chosen as the main hemodynamic indicator.

When analyzing the results of bicycle ergospirometry, we analyzed indicators that were more dependent on the hemodynamic state, namely the relative power at the aerobic threshold (AeP power, W/kg), MIC, ml/min/kg and the rate of heart rate recovery (bpm) after testing.

Statistical data analysis was carried out using Excel software packages (Microsoft Office 2016). The mean (M), standard deviation (SD), minimum and maximum values were calculated. Comparative analysis was carried out using Student's t-test; differences were considered significant at $p<0,05$.

Athletes who took part in the study were informed about the goals and methodology of the study, which was conducted in accordance with the principles of the 2013 World Health Organization Declaration of Helsinki. All participants and/or their official representatives gave written voluntary informed consent to participate in the study in an anonymized form, as well as further processing of the obtained data for scientific purposes.

Results of the study and discussion. According to hemodynamic monitoring data in an active orthotest in groups of athletes with disabilities, despite the age-related decrease in heart rate typical of athletes of cyclic sports, no significant decrease in either the lying or standing heart rate was detected (Table 2).

The end-diastolic volume of the heart in the supine position in female athletes with disabilities increases from 112.17±7.31 (100–121) ml at 11-12 years old to 150±32.9 (117–202) ml in the group of female athletes 18 -20 years. A significant increase in the supine CDI occurs in training athletes with disabilities at the age of 13-14 years compared to 11-12 years, however, at an older age, no significant changes in either the supine CDI or the standing CDI were detected. At the same time, the KDI of female racers has a constant significant increase, increasing by 20% from the age of 11-12 years to 20 years. If at the age of 11-12 years the CDI of lying and CDI of standing in athletes with disabilities and healthy athletes did not have significant differences, then at the age of 13-14 years the CDI of standing of female skiers was significantly higher, and at an older age there was a tendency for a significant superiority of CDI of female skiers over athletes with HIA applies to both positions: lying down, as in medical examinations, and standing, as in competitive activities.

A reliable dependence of high physical performance [1, 2] on large volume parameters of the heart has been established. However, in athletes with disabilities, despite sufficient volumetric parameters of the cardiosystem in the supine position at the ages of 13-14 years and 18-20 years, a significantly low power at

Table 2. Age-related features of the hemodynamic state of female athletes involved in endurance sports

Age, years	Groups	Heart rate, bpm				CDI, ml/m²				MOC, ml/min/kg
		Lying down		Standing		Lying down		Standing		
11-12	Disabilities	70,33±5,2 (65–80)		86±6,07 (78–94)		81±6,96 (69–90)		70,17±4,67 (65–77)		45±6,61 (37,5–53,9)
	Female skiers	65,75±4,59 (59–75)		82,83±10,84 (65–99)		86,75±6,62 (77–99)		73,83±6,15 (66–83)		45,4±5,16 (36,8–49,1)
13-14	Disabilities	60±12,25 (45–75)		74,25±20,01 (54–100)		94,25±3,2 (91–97)**		75,75±7,5 (68–86)	▲	43±7,48 (37–51,4)
	Female skiers	62,11±7,53 (48–76)		79,28±10,57 (56–90)		95,83±4,74 (87–104)*		81,78±7,2 (68–96)		53,1±9,15 (36,2–72)
15-17	Disabilities	64,25±2,22 (61–66)		81,25±8,06 (70–88)		90,75±10,21 (85–104)	▲	72,75±9,84 (60–84)	▲	54,1±4,66 (50,3–59,3) *
	Female skiers	57,9±6,65 (46–73)		75,27±9,06 (60–88)		99,92±5,98 (85–113)*		82,06±6,77 (70–94)		53,8±5,94 (44,7–68,5)
18-20	Disabilities	56,2±13,55 (37–72)		73,2±15,66 (46–86)		94,6±12,5 (82–114)	▲	81,6±12,36 (63–97)		48,1±9,12 (35–56,3) *
	Female skiers	55,44±5,2 (47–65)		71,44±7,89 (54–78)		103±10,17 (91–120)*		86,78±5,8 (82–100) *		53,83±3,25 (49–59,2)

** differences are significant ($p<0.01$) between the marked group and the previous age group*
***differences are significant ($p<0.05$) between the marked group and the previous age group*
▲ the differences are significant ($p<0.05$) between the group of healthy athletes and athletes with disabilities

the aerobic threshold was revealed relative to healthy athletes, reduced power at the ANNO and, accordingly, the power of the VO_2 max, which is determined low oxygen consumption. The probable reasons for low powers at the physiological thresholds of energy supply are not strength abilities, but insufficiently high CDI standing, limiting the aerobic abilities of female athletes. At the same time, female athletes of the same age do not have significant differences in heart rate values on AeP and PANO, and also have an equally high recovery rate (more than 30 beats/min).

The average value of modulators that describe the hemodynamic state of athletes, namely volemia (fullness of the vascular bed, or the correspondence of the volume of circulating blood to the volume of the vascular bed), inotropy - the force of contraction of the heart muscle and vascular tone in groups of athletes of the same age did not have significant differences.

It is important to note that the coefficient of variation (the ratio of the standard deviation to the mean value) in groups of young athletes with disabilities is in the range of 3-10%, and in the age groups of 15-17 years and 18-20 years of athletes with disabilities it is 13-15% , that is, in older groups of athletes with disabilities, the data varies more widely. Thus, the data obtained justify the need to individualize the training process of athletes with disabilities with stage-by-stage complex control for timely correction in the training process.

Conclusions. Despite the fact that a decrease in resting heart rate determines the physiological adaptation of the cardiosystem to regular training in endurance sports, no significant differences in heart rate in the orthotest were found in the groups of female athletes examined. When analyzing the functional state of athletes, it is advisable to take into account the parameters of the hemodynamic state, especially in the vertical position of the body. For the full development of the sports potential of athletes with disabilities, stage-by-stage comprehensive control in the training process and its individualization are necessary.

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