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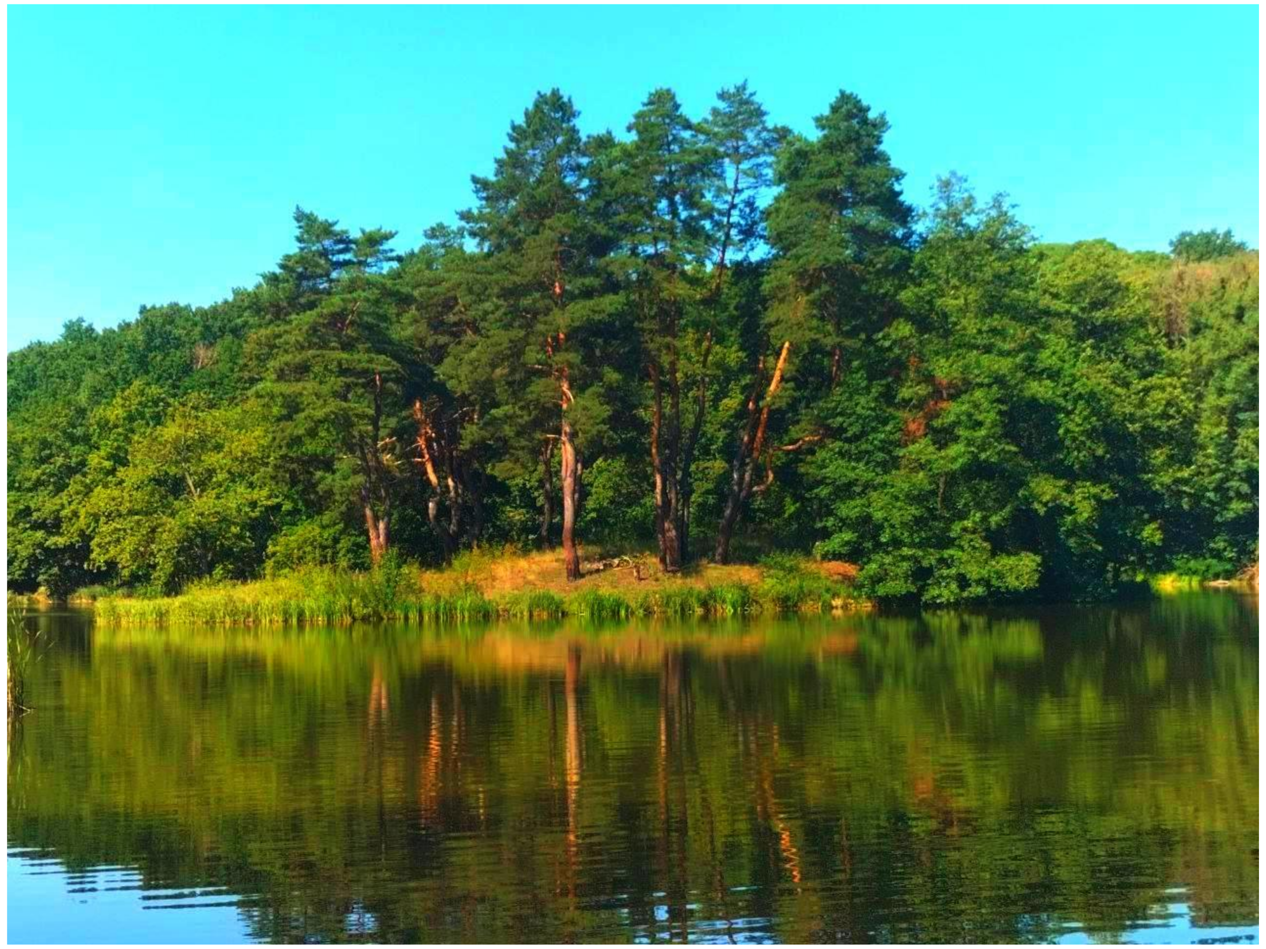

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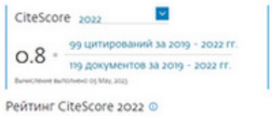

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ORIGINAL ARTICLES. SPORT

Effect of the identical training process on the functional state of high-level sprint swimmers of both genders

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Purpose: to study the effect of an identical training process on the functional state of high-level sprint swimmers of both genders.

Material and methods. The heart rate variability indices, central hemodynamic parameters and $PWC_{170/kg}$ measurements were compared between 86 male and 42 female swimmers with sports qualifications from first-class athlete to Master of Sports International Class, and separately, – between 38 males and 9 females (Masters of Sports and Masters of Sports International Class), 28 males and 16 females (Candidates for Masters of Sports), and 22 males and 17 females (first-class athletes).

The results. In the general group (86 males vs. 42 females) only the greater value of $PWC_{170/kg}$ in males by 12.64 % (p<0.001) was revealed, without any differences in heart rate variability and central hemodynamics. Masters of Soprts and Masters of Sports International Class, as well as Candidates for Masters of Sports, didn't have gender differences in all indicators studied. In first-class athletes, there were no gender differences in heart rate variability and central hemodynamic parameters, except for $PWC_{170/kg}$, which in males was greater by 11.27 % (p=0.036).

Conclusions. A comparison of 86 male and 42 female swimmers with sports qualifications from first-class athlete to Master of Sports International Class, who differed by age and training experience, showed no significant differences in HRV and central hemodynamic parameters except for $PWC_{170/kg}$, which was 12.64 % higher in males (p<0.001). There were no significant differences between all studied indices in 38 male and 9 female swimmers with sports qualifications Master of Sports and Master of Sports International Class, with no differences in age or training experience. Comparison of 28 male and 16 female swimmers with sports qualification Candidate for Master of Sports, not differing by age and training experience showed no significant differences in HRV and central hemodynamic parameters, except for $PWC_{170/kg}$, which was greater in males by 11.27 % (p=0.034). In 22 male and 17 female swimmers with sports qualification first-class athlete, not differing by age (males have greater training experience) there were no differences between all studied indices.

Keywords: sprint swimmers, heart rate variability, central hemodynamics, physical working capacity

Анотація

Євген Михалюк, Єгор Гороховський, Анатолій Босенко, Надія Орлик, Марія Топчій. Вплив ідентичного тренувального процесу на функціональний стан плавців високого класу обох статей

Мета: вивчити вплив ідентичного тренувального процесу на функціональний стан плавців-спринтерів високого класу обох статей.

Матеріал і методи. Проведено порівняння показників варіабельності серцевого ритму, параметрів центральної гемодинаміки та $PWC_{170/кг}$ у 86 чоловіків та 42 жінок – плавців зі спортивною кваліфікацією від спортсмена першого розряду до майстра спорту міжнародного класу, та окремо – 38 чоловіків та 9 жінок (майстри спорту та майстри спорту міжнародного класу), 28 чоловіків та 16 жінок (кандидати у майстри спорту) і 22 чоловіків та 17 жінок (спортсмени першорозрядники).

Результати. У загальній групі (86 чоловіків і 42 жінки) у чоловіків виявлено більше на 12,6 % (p<0,001) значення $PWC_{170/кг}$, ніж у жінок, а відмінностей у показниках варіабельності серцевого ритму і центральної гемодинаміки були відсутні. Серед майстрів спорту та майстрів спорту міжнародного класу, а також кандидатів у майстри спорту гендерних відмінностей за всіма досліджуваними показниками не виявлено. У спортсменів першого розряду гендерних відмінностей за показниками варіабельності серцевого ритму і центральної гемодинаміки також не встановлено, за винятком показника $PWC_{170/кг}$, який у чоловіків був більшим на 11,27 % (p=0,036), ніж у жінок.

Висновки. Порівняння 86 чоловіків і 42 жінок-плавців зі спортивною кваліфікацією від спортсмена першого розряду до майстра спорту міжнародного класу, які відрізняються за віком і досвідом тренувань, не виявило істотних відмінностей у ВСР і параметрах центральної гемодинаміки, за винятком показника $PWC_{170/кг}$, який у чоловіків був більшим на 12,64 % (p<0,001). У 38 чоловіків і 9 жінок – плавців зі спортивною кваліфікацією майстер спорту і майстер спорту міжнародного класу, які не мають відмінностей у віці та тренувальному стажі, не було виявлено значних відмінностей між усіма досліджуваними показниками. Порівняння 28 чоловіків і 16 жінок, плавців зі спортивною кваліфікацією кандидат у майстри спорту, які не відрізняються за віком і тренувальним стажем, не виявило суттєвих відмінностей у ВСР і параметрах центральної гемодинаміки, за винятком $PWC_{170/кг}$, що був більшим у чоловіків на 11,27 % (p=0,034). У 22 чоловіків і 17 жінок, які мають спортивну кваліфікацію спортсмен першого розряду, та не відрізняються за віком (у чоловіків більший тренувальний стаж), не було виявлено відмінностей між усіма досліджуваними показниками.

Ключові слова: плавці-спринтери, варіабельність серцевого ритму, центральна гемодинаміка, фізична працездатність

Аннотация

Евгений Михалюк, Егор Гороховский, Анатолий Босенко, Надежда Орлик, Мария Топчий. Влияние идентичного тренировочного процесса на функциональное состояние пловцов высокого класса обоего пола

Цель: изучить влияние идентичного тренировочного процесса на функциональное состояние пловцов-спринтеров высокого класса обоего пола.

Материал и методы. Проведено сравнение показателей вариабельности сердечного ритма, параметров центральной гемодинамики и $PWC_{170/кг}$ 86 мужчин и 42 женщин – пловцов со спортивной квалификацией от спортсмена первого разряда до мастера спорта международного класса, и отдельно – 38 мужчин и 9 женщин (мастера спорта и мастера спорта международного класса), 28 мужчин и 16 женщин (кандидаты в мастера спорта) и 22 мужчин и 17 женщин (спортсмены перворазрядники).

Результаты. В общей группе (86 мужчин и 42 женщины) у мужчин обнаружено большее на 12,6 % (p<0,001) значение $PWC_{170/кг}$, чем у женщин, а различия показателей вариабельности сердечного ритма и центральной гемодинамике отсутствовали. Среди мастеров спорта и мастеров спорта международного класса, а также кандидатов в мастера спорта гендерных различий по всем изучаемым показателям не выявлено. У спортсменов первого разряда гендерных различий по показателям вариабельности сердечного ритма и центральной гемодинамики также не установлено, за исключением показателя $PWC_{170/кг}$, который у мужчин был больше на 11,27 % (p=0,036), чем у женщин.

Выводы. Сравнение 86 мужчин и 42 женщин – пловцов со спортивной квалификацией от спортсмена первого разряда до мастера спорта международного класса, различающихся по возрасту и опыту тренировок, не выявило существенных различий в ВСР и параметрах центральной гемодинамики, за исключением показателя $PWC_{170/кг}$, который у мужчин был больше на 12,64 % (p<0,001). У 38 мужчин и 9 женщин – пловцов со спортивной квалификацией мастер спорта и мастер спорта международного класса, не имеющих различий в возрасте и тренировочном стаже, не было выявлено значительных различий между всеми изучаемыми показателями. Сравнение 28 мужчин и 16 женщин – пловцов со спортивной квалификацией кандидат в мастера спорта, не отличающихся по возрасту и тренировочному стажу, не выявило существенных различий в ВСР и параметрах центральной гемодинамики, за исключением $PWC_{170/кг}$, который был больше у мужчин на 11,27 % (p=0,034). У 22 мужчин и 17 женщин, имеющих спортивную квалификацию спортсмен первого разряда, не различающихся по возрасту (у мужчин больше тренировочный стаж), не было выявлено различий между всеми исследуемыми показателями.

Ключевые слова: пловцы-спринтеры, вариабельность сердечного ритма, центральная гемодинамика, физическая работоспособность

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Introduction

Physical activity is a serious challenge for the cardiovascular apparatus because it engages the chronotropic, inotropic, preload, and postload reserves. Regular physical exercise induces some physiological adaptations leading to increased heart volume and mass. There appear to be several gender-specific physiological and morphological differences in cardiovascular adaptation and adjustment to dynamic exercise in humans. In this regard, gender may play an important role in determining these changes and adaptations to dynamic exercise because of genetic, endocrine, and body composition differences between men and women. In women, compared with men, vasoconstriction is decreased, and vascular resistance is reduced, especially after exercise. Significant differences also exist in the adaptation of the cardiovascular system to physical exercise: female athletes have a smaller heart volume and wall thickness than male athletes [1].

Analysis of studies concerning gender differences should start with non-athletes. Thus, Koenig et al. presented an extensive metanalysis of 63612 people (31970 women), in which he showed that women had significantly lower mean RR intervals and standard deviation of RR intervals than men [2]. Meanwhile, spectral analysis of heart rate variability (HRV) power was characterized by significantly greater high-frequency (HF) and less low-frequency (LF) power; i.e., a lower sympatho-vagal index ratio. The meta-regression revealed a significant effect of age. Women showed higher mean heart rate (HR) and vagal activity as determined by the power of the HF component of HRV. The influence of age on HRV indices is also evidenced by G.D. Spina et al. and A. Voss et al. Thus, Spina et al., examined 485 subjects who were divided into 3 age groups (18–39, 40–59 and ≥60 years) and found that women had better vagal tone indicators, while men had a stronger sympathetic influence of the autonomic nervous system (ANS) [3]. Voss et al., comparing 782 women and 1124 men who were divided into 5 age groups (25–34, 35–44, 45–54, 55–64, and 65–74 years) found significant modifications in HRV indices depending on gender, especially in the frequency domain and in correlation analysis [4]. In addition, significant modifications depending on age were observed in almost all domains. Interestingly, gender differences disappeared in the last two age decades, and age correlations disappeared in the last decade. A decrease in vagal activity on HRV in 47 male versus 39 female college students was reported by Suh, who attributes this to higher levels of stress and lower levels of depression in men affecting the decrease in vagal activity [5]. Thus, the presence of lower values of mean RR intervals, the influence of age on HRV indices, and the prevalence of vagal tone in women are characteristic for non-sportsmen.

The actual problem of modern sports is the analysis of the mechanisms of adaptive restructuring in the female body under the effect of sports, the diagnostics of the functional state compared to the male body, and, accordingly, the principles of creating the training process, which has differences or correspond with the training of male athletes of a similar sport and skill level [6, 7].

Our works have demonstrated that the long-term training process has the same effect on male and female athletes, which is expressed in reduction, and sometimes without significant differences in the ECG (contractility, pumping function, conduction abnormality, the presence of pre-excitation and prolonged QT interval syndromes), cardiac index values, type of hemodynamics, HRV integral indices (LF/HF ratio, stress-index), relative value of physical performance ($PWC_{170/kg}$), etc. [6, 8, 9].

In particular, as the sports qualification of swimmers raises from city champion to international champion, there is a noticeable decrease in the differences among ECG parameters between males and females, and among 400 m runners, there are no significant differences in the regularity of sinus rhythm, ECG voltage, the number of persons with normal heart axis, heart rate within 61–79 beats·min^{-1} [6].

Wooten et al. reported the results of echocardiographic examination of 109 men (60±12 years) and 55 women (57±12 years) participants in the World Veterans Athletics Championships, in whom left ventricular mass index, systolic and diastolic blood pressure, left ventricular ejection fraction and stroke volume index were not different between the genders [10]. The authors believe that lifelong physical training does not exacerbate morphological differences in cardiac risk or dysfunction in both male and female athletes.

Meanwhile, amid reports that there are no gender differences among indicators characterizing the functional state of athletes, there are opposite results showing the upward trend in some indicators in male athletes. Thus, a study by Guang et al. among 308 youth swimmers, including 137 girls and 171 boys aged from 8 to 16 years of various

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training levels, showed boys had greater ($p<0.05$) means for all hematological parameters, except for erythropoietin and these variables demonstrated an increase with training in boys [11]. The mean maximum oxygen uptake and peak anaerobic power were also greater in boys (2.91±0.08 $l\cdot min^{-1}$ and 547±28 W) than in girls (2.25±0.07 $l\cdot min^{-1}$ and 450±26 W). Data from Arena et al., which studied the differences in resting blood pressure for 8 weeks in the competitive period in collegiate swimmers (15 males and 23 females) demonstrated that the increased systolic and diastolic blood pressure was significantly higher in males than in females [12]. P. Bauer et al. also found significantly higher values of systolic blood pressure in 33 handball players (26±5 years) compared to 18 soccer players (22±3 years), respectively 124±8 versus 115±8 mm Hg ($p<0.001$) [13]. We consider it somewhat incorrect to compare older male handball players with female soccer players. Further, Bauer et al. without indicating sport and physical performance, comparing professional athletes (47 males and 25 females) of the same age, noted considerably higher blood pressure values in males after bicycle ergometry (202±20 vs. 177±15 mm Hg, $p<0.001$), and the initial resting blood pressure values were comparable in them [14].

The aim of this work was to study the influence of an identical training process on the functional state of elite sprint swimmers of both genders.

Material and methods

Participants

Analysis of heart rate variability, central hemodynamic parameters and physical working capacity was carried out in 86 male and 42 female Ukrainian sprint swimmers with sports qualifications from first-class athlete to Master of Sports International class (general group). The studied parameters were compared separately for swimmers with sports qualifications Master of Sports and Master of Sports International Class (MS group); Candidate for Masters of Sports (CMS group); first-class athlete (FCA group). The number of male and female swimmers in the groups is shown in table 1. .

Table 1

Number of male and female swimmers in groups

Group	Sports Qualification	Males	Females
General group	From first-class athlete to Master of Sports International Class	n=86	n=42
MS group	Master of Sports, Master of Sports International Class	n=36	n=9
CMS group	Candidate for Masters of Sports	n=28	n=16
FCA group	First-class athlete	n=22	n=17

Ethical consent was provided by the ethics committee of the local institution and in accordance with the Helsinki declaration.

Procedure

Mathematical and spectral methods of heart rate variability (HRV) analysis were used to assess the autonomic regulation of cardiac activity. 5-minute short ECG recordings (Cardio+, Meteocol LLC, Ukraine) were used for the HRV analysis according to the International Standard [15].

To evaluate the autonomic regulation of cardiac activity, mathematical methods for analysis of HRV parameters were used: mode (Mo, s), mode amplitude (AMo, %), variation range (D, s). A number of derived indices were calculated: autonomic equilibrium index (AMo/D, %/s), autonomic rhythm index (ARI, $1/s^2$), adequacy of regulation processes (ARP, %/s), stress index (SI), r.u. The frequency HVR components were assessed analysing the spectral indicators of autocorrelation functions: total spectral power (TP) (ms^2), spectral components of the very low frequency (VLF) (ms^2), low frequency (LF) (ms^2) and high frequency (HF) (ms^2), LF and HF normalized values (LFn, %, HFn, %), LF/HF ratio, relative units (r.u.).

Central hemodynamics (CH) was studied by the automated tetrapolar rheography method (Cardio+, Meteocol LLC, Ukraine). Stroke volume (SV) and cardiac output (CO), stroke volume

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index (SVI), cardiac index (CI), systemic vascular resistance (SVR), and systemic vascular resistance index (SVRI) were calculated.

Physical working capacity was measured according to the generally accepted technique on a stationary cycle ergometer (Corival, Lode, Netherlands) using the PWC_{170} submaximal test with further calculation of the relative value of physical working capacity ($PWC_{170/kg}$) [16].

Statistical analysis

Statistical analysis of the data was performed using Statistica for Windows 13 (StatSoft Inc.). The data were checked for normality using the Shapiro-Wilk test. Normally distributed data reported as mean ± SD, non-normally distributed data reported as median (1st quartile; 3rd quartile). Mann-Whitney test (for non-normally distributed data) and Student's paired t-test (for normally distributed data) were used to compare values between groups. The chi-square test was used to compare the frequencies of qualitative characteristics between the groups. Statistical significance was accepted at $p \leq 0.05$.

Results

When comparing anthropometric measurements, age and training experience of swimmers in the general group (table 2), it was found that males and females differed in age, training experience, body length and body weight. These parameters were greater in male swimmers. Male and female swimmers of the MS and CMS groups didn't differ by age and training experience. At the same time, body length and body weight in males were significantly greater. In male and female swimmers of the FCA group, the age of males didn't differ from the age of females. Training experience, body length and body weight of males in this group were significantly greater than those of females.

Table 2

General characteristics of the surveyed swimmers

Groups	Gender	n	Median (Q1; Q3)	U test statistic	Z-score	p value
Age (years)						
General group	Males	86	16 (15; 19)	1013.50	-4.02	<0.001
	Females	42	15 (14; 16)			
MS group	Males	36	18.5 (17; 20)	103.00	-1.66	0.100
	Females	9	16 (16; 17)			
CMS group	Males	28	16 (15; 18)	132.50	-2.22	0.026
	Females	16	15 (14; 16)			
FCA group	Males	22	14 (14; 16)	140.00	-1.32	0.188
	Females	17	14 (14; 15)			
Body length, cm						
General group	Males	86	182 (177; 186)	368.50	-7.29	<0.001
	Females	42	168.5 (164; 172)			
MS group	Males	36	186 (182.5; 190)	25.00	-3.87	<0.001
	Females	9	170 (170; 174)			
CMS group	Males	28	182 (178; 183)	22.50	-4.903	<0.001
	Females	16	167.5 (163.5; 170)			
FCA group	Males	22	175 (170; 178)	95.00	-2.59	0.001
	Females	17	168 (164; 172)			

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Body weight, kg						
General group	Males	86	70 (64; 76)	503.00	-6.61	<0.001
	Females	42	57 (53; 62)			
MS group	Males	36	77 (72; 84)	33.00	-3.65	<0.001
	Females	9	62 (60; 68)			
CMS group	Males	28	69 (65; 73.5)	45.50	-4.34	<0.001
	Females	16	56 (63; 60)			
FCA group	Males	22	61.5 (58; 67)	96.50	-2.55	0.011
	Females	17	56 (50; 59)			
Training experience, years						
General group	Males	86	8 (7; 10)	1122.50	-3.23	0.001
	Females	42	7 (6; 9)			
MS group	Males	36	10 (8.5; 11.5)	126.50	-0.99	0.321
	Females	9	10 (8; 10)			
CMS group	Males	28	8 (6; 10)	171.00	-0.81	0.416
	Females	16	8 (6; 9)			
FCA group	Males	22	7 (7; 8)	105.50	-2.29	0.022
	Females	17	6 (6; 7)			

Analysis of temporal indices of HRV of male and female swimmers in the general group showed no differences in AMo – 31.514 (24.335; 43.206) vs. 29.657 (25.723; 37.949) %, p=0.470, AMo/D – 69.327 (41.952; 145.885) vs. 78.044 (42.900; 113.607) %/s, p=0.986, ARP – 35.317 (25.826; 45.575) vs. 34.020 (27.053; 51.247) %/s, p=0.810, SI – 36.565 (23.633; 64.306) vs. 45.192 (23.991; 76.750) r.u., p=0.603, D –0.467 (0.333; 0.579) vs. 0.377 (0.319; 0.542) s, p=0.314, and ARI – 2.406 (1.906; 3.867) vs 2.990 (2.252; 4.239) 1/s^2, p=0.143. Analysis of the spectral indices of heart rate variability also showed no differences in LF – 384.000 (254.000; 528.000) vs. 296.500 (195.000; 451.000) ms^2, p=0.132, VLF – 1024.000 (398.000; 2231.000) vs. 845.500 (369.000; 1470.000) ms^2, p=0.270, LF/HF ratio – 1.500 (0.770; 2.120) vs. 1.135 (0.360; 1.870) r.u., p=0.096, and HF – 258.500 (215.000; 342.000) vs. 336.000 (219.000; 446.000) ms^2, p=0.107 in males and females.

In male and female swimmers of the MS group, temporal HRV indices were: AMo – 33.549 (25.169; 43.900) vs. 28.306 (25.129; 38.484) %, p=0.580, AMo/D – 73.352 (49.831; 145.531) vs. 75.897 (42.468; 114.357) %/s, p=0.898, ARP – 36.153 (25.169; 46.087) vs. 38.066 (23.639; 50.368) %/s, p=0.996), D – 0.443 (0.345; 0.543) vs. 0.365 (0.337; 0.544) s, p=0.630. The stress index (SI) of regulatory systems, which reflects the degree of centralization of heart rhythm control, also didn't differ between males and females and was, respectively 36.715 (26.014; 62.932) and 49.571 (19.836; 76.805) r.u., p=0.987. The following results were obtained for spectral HRV indices: LF – 388.500 (252.000; 526.500) vs. 332.500 (204.000; 487.500) ms^2, p=0.262, VLF – 1031.000 (413.500; 2588.500) vs. 928.000 (383.500; 2003.000) ms^2, p=0.274, LF/HF ratio – 1.460 (0.685; 2.035) vs. 1.740 (0.380; 2.555) r.u., p=0.182, and HF – 284.000 (212.000; 435.000) vs. 244.500 (204.500; 435.500) ms^2, p=0.182.

There were no differences in the studied HRV indices among the swimmers of the CMS group. Thus, temporal HRV indices in males and females were: AMo – 30.373 (23.586; 43.752) vs. 28.306 (25.129; 38.484) %, p=0.724, AMo/D – 71.885 (37.861; 164.710) vs. 75.897 (42.468; 114.357) %/s, p=0.798, ARI – 2.845 (1.570; 4.468) vs. 3.213 (2.047; 4.112) 1/s^2, p=0.990, ARP – 35.108 (23.991; 46.514) vs. 38.066 (23.639; 50.368) %/s, p=0.767, and SI – 38.871 (22.194; 87.550) vs. 49.571 (19.836; 76.805) r.u., p=0.990. The following results were obtained for spectral HRV indices: LF – 435.000 (299.000; 585.000) vs. 332.500 (204.000; 487.500) ms^2, p=0,184, LF/HF ratio – 1.730 (1.110; 2.400) vs. 1.740 (0.380; 2.555) r.u., p=0.479, HF – 248.000 (210.500; 275.500) vs. 244.500 (204.500; 435.500) ms^2, p=0.855, and VLF (1221.500 (304.500; 2563.000) vs. 928.000 (383.500; 2003.000) ms^2, p=0.817.

Similarly to the results above, we also didn`t find any gender differences in HRV parameters in the swimmers of the FCA group. Thus, temporal HRV indices in them were: AMo – 29.717 (23.295; 39.444) vs. 30.464 (25.962; 36.658) %, p=0.989, AMo/D – 52.172 (34.140; 76.740) vs. 79.868 (54.227; 102.491) %/s, p=0.251, and SI – 30.139 (23.307; 47.963) vs. 45.550 (36.152; 76.750) r.u., p=0.198. The spectral indices of HRV were, respectively: LF – 313.500 (222.000; 400.000) vs. 302.000 (214.000; 446.000) ms^2, p=1.000, LF/HF ratio – 1.135 (0.670; 2.140) vs. 1.260 (0.390; 1.690) r.u., p=0.581, VLF – 669.500 (491.000; 1974.000) vs. 718.000 (379.000; 1459.000) ms^2, p=0.681, HF – 270.000 (222.000; 339.000) vs. 328.000 (241.000; 453.000) ms^2, p=0.165.

As to the central hemodynamics in male and female swimmers in the general group, SVR was 1210.750 (1109.200; 1351.500) vs. 1293.450 (1173,200; 1464,600) $dn{\cdot}s{\cdot}sm^{-5}$, p=0.045, and SVRI was greater in males – 29.595 (25.850; 31.880) vs. 26.470 (23.710; 30.480) r.u., p=0.014. There were no differences in SVI – 48.265 (45.590; 53.270) vs. 48.010 (45.650; 54.110 $ml{\cdot}m^{-2}$, p=0.758 and CI – 2.802 (2.606; 3.050) vs. 3.007 (2.699; 3.336) $l{\cdot}min^{-1}{\cdot}m^{-2}$, p=0.05, which corresponded to a eukinetic type of hemodynamics (TH). The distribution by TH in males was as follows: 41.86 %:51.16%:6.98 %, and in females 30.95%:61.90%:7.15%, hypokinetic, eukinetic, and hyperkinetic TH, respectively. However, only in males a significant prevalence of eukinetic TH over hyperkinetic TH was found (p=0.041), confirming the mean CI values.

A comparison of the number of swimmers and the ratio between males and females showed the following: 41.86 % (n=36) vs. 30.95 % (n=13) p=0.489 – with hypokinetic TH, 51.16 % (n=44) vs. 61.9 % (n=26) p=0.382 – with eukinetic TH and 6.98 % (n=6) vs. 7.15 % (n=3) – with hyperkinetic TH, p=0.992 i.e. the number of athletes of both genders in this group was comparable.

The following results were obtained for central hemodynamic parameters in athletes of the MS group: CI – 2.751 (2.564; 2.905) vs. 2.997 (2.668; 3.413) $l{\cdot}min^{-1}{\cdot}m^{-2}$, p=0.115, with both values corresponding to the eukinetic TH. Males had a greater value of SVRI – 30.240 (27.075; 33.760) vs. 26.420 (23.145; 28.980) r.u., p=0.036, but no gender differences in SVR were found (1206.400 (1108.850; 1331.550) vs. 1298,600 (1156,450; 1513,850) $dn{\cdot}s{\cdot}cm^5$, p=0.523).

The distribution by TH in males was 41,7 %:52,8 %:5,5 %, and in females – 33,3 %:66,7 %:0%, hypokinetic, eu- and hyperkinetic TH, respectively. However, there were no statistically significant differences between the ratio of TH in both males and females. It should also be noted that there were no female athletes with hyperkinetic TH.

A comparison of the number of athletes with hypo- and eu- TH between males and females showed no significant differences: 41.7 % (n=15) vs. 33.3 % (n=3) p=0.786 and 52.8 % (n=19) vs. 66.7 % (n=6) p=0.549, respectively, i.e., the number of swimmers in the compared groups with hypo- and eukinetic TH was comparable and had no differences.

There were no gender differences in central hemodynamic parameters in swimmers of the CMS group. Thus, SVI in males and females was 49.035 (44.535; 53.305) vs. 48.070 (44.880; 53.605) p=0.855 $ml{\cdot}m^2$, p=0,855, CI – 2.862 (2.585; 3.045) vs. 2.997 (2.668-3.413) $l{\cdot}min^{-1}{\cdot}m^{-2}$, p=0,257, corresponding to eukinetic TH, SVR –1251.950 (1093.050; 1394.900) vs. 1298.600 (1156.450; 1513.850) $dn{\cdot}s{\cdot}cm^{-5}$, p=0,289 and SVRI – 29.205 (25.495; 31.850) vs. 26.420 (23.145l; 28.980) r.u., p=0,116.

The distribution of THs in males was 42.8%:53.6%:3.6% and in females it was 25.0%:62.5%:12.5%, hypokinetic, eu-, and hyperkinetic TH, respectively. Significant prevalence of eukinetic TH over hyperkinetic TH (p=0.005) and hypokinetic TH over hyperkinetic TH (p=0.02) was found in males, and there were no significant differences between THs ratios in females. The obtained data confirm the mean CI values for the prevalence of eukinetic and hypokinetic TH over hyperkinetic TH in males.

A direct comparison of the number of swimmers and the ratio of TH between males and females revealed the following: 42.80 % (n=12) vs. 25.0 % (n=4), p=0.526 for hypokinetic TH, 53.6% (n=15) vs. 62.5 % (n=10), p=0.659 for eukinetic TH and 3.6 % (n=1) vs. 12.5 % (n=2), p=0.574 for

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hyperkinetic TH, meaning the number of athletes of both genders was comparable.

The analysis of central hemodynamic parameters in swimmers of the FCA group also showed no gender differences. Thus, SVI in males and females was 49,035 (44,535; 53,305) vs. 48,070 (44,880; 53,605) ml·m^2, p=0,855, CI – 2,862 (2,585; 3,045) vs. 2,997 (2,668; 3,413) l·min^{-1}·m^{-2}, p=0,257, which corresponds to the eukinetic TH, SVR – 1251,950 (1093,050; 1394,900) vs. 1298,600 (1156,450; 1513,850) dn·s·cm^{-5}, p=0,289, SVRI – 29,205 (25,495; 31,850) vs. 26,420 (23,145; 28,980) r.u., p=0,116.

The distribution of males by TH was 36.4%:50.0%:13.6%, and for females – 35.3%:58.8%:5.9%, respectively hypokinetic, eu- and hyperkinetic TH. There were no significant differences between THs ratios in males, while a significant prevalence of eukinetic TH compared to hyperkinetic TH was found in females (p=0,035). The obtained data confirm the mean CI values about the prevalence of eukinetic TH in females.

A direct comparison of the number of swimmers and the ratio of THs between males and females showed the following: 36.4 % (n=8) vs. 35.3 % (n=6) p=0.966 with hypokinetic TH, 50.0 % (n=11) vs. 58.8 % (n=10) p=0.686 for eukinetic TH, 13.6 % (n=3) vs. 5.9 % (n=1) – with hyperkinetic TH, i.e. the number of male and female swimmers in the group with different THs was comparable.

The relative value of physical working capacity (table 3) in male swimmers in the general group was 12.64 % (p<0.001) higher than in female swimmers. $PWC_{170/kg}$ in males and females of the MS group didn't differ.

In males of the CMS group, the $PWC_{170/kg}$ was 16.52±0.51 kgm·min^{-1}·kg^{-1} which 11.27 % greater than in females (p=0.034). In male swimmers of the FCA group, the mean value of $PWC_{170/kg}$ didn't differ from that of females.

Table 3

$PWC_{170/kg}$ measurements

Group	Gender	n	$PWC_{170/kg}$	t statistic	p value
General group	Males	86	17.17±2.857	t(126)= -3.96	<0.001
	Females	42	15.01±2.994		
MS group	Males	36	18.37±2.251	t(43)= -1.45	0.153
	Females	9	16.98±3.670		
CMS group	Males	28	16.52±2.704	t(42)= -2.19	0.034
	Females	16	14.66±2.733		
FCA group	Males	22	16.02±3.284	t(37)= -1.81	0.079
	Females	17	14.28±2.522		

Discussion

In the available sports medicine literature, we did not find research devoted to gender differences in heart rate variability and central hemodynamics in swimmers, except for our previously published works [17, 6]. Comparisons of the studied parameters, in which 12 male and 18 female international and national champion swimmers participated, showed no significant differences in the values of HRV, CI, types of hemodynamics and $PWC_{170/kg}$, while swimmers of both genders in 2004 had hypokinetic TH, and at present – eukinetic TH [6]. An early study in 2004, which involved 33 male and 9 female international and national champion swimmers, also showed no difference among the CI values [17].

Comparison of the studied indicators of 13 male and 13 female nationally ranked swimmers showed the prevalence of parasympathetic effects of ANS in females and the absence of significant differences in CI, TH and $PWC_{170/kg}$ [6]. The participants of the present study also did not have significant differences in the HRV and CH parameters, except for $PWC_{170/kg}$, which was greater in males by 11.27 % (p = 0.036). A 2004 study, when comparing 14 male and 8 female nationally ranked swimmers, also showed insignificant differences in the HRV and CH parameters [17].

Thus, a comparison of the studied indicators

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characterizing the autonomic nervous system and central hemodynamics in international and national champion as well as in nationally ranked swimmers indicates insignificant differences between male and female athletes.

Some recent research provides information on gender differences in maximum oxygen uptake (MOU) in swimmers. It should be noted that the results of the submaximal PWC_{170} test are often used as a marker of maximal oxygen uptake. Back in 1988, Karpman et al. showed a high positive correlation (r=0.905) between PWC_{170} values and MOU in athletes, which allows us to discuss the obtained results of gender differences in physical performance indicators using MOU values [16].

Thus, a comparison of MOU values in 20 elite badminton players and 16 female badminton players of the same age showed a significantly higher aerobic capacity in men with no significant differences in HRV indices [18]. Surveys conducted in the strongest cross-country skiers from Norway, Russia and Switzerland with comparable volume of training loads in males and females ($p<0.05$) also testify to the prevalence of MOU values in males and higher markers of sympathetic activity due to significantly higher sympatho-vagal index ($p=0.015$) [19]. Similar results were obtained by E. Ramalho et al., which showed a higher LF/HF ratio in 22 males and 27 females ($p<0.05$) engaged in power sports [20].

As for swimmers, according to Reis et al., comparison of 8 female (mean age 17.9±3.5 years) and 11 male (mean age 21.9±2.8 years) well-trained swimmers showed a significant prevalence of MOU/kg in males (4.49±0.585 $l{\cdot}min^{-1}$ vs 2.75±0.187 $l{\cdot}min^{-1}$, $p\leq0.001$) [21]. A similar comparison of low-skill swimmers from 8 to 16 years old also showed the prevalence of the VO_2 max value in boys, respectively 2.91±0.08 $l{\cdot}min^{-1}$ vs 2.25±0.07 $l{\cdot}min^{-1}$ [11].

In our work, when comparing the data obtained from 86 male (average age 16.96±0.27 years) and 42 female (average age 15.14±0.35 years, $p<0.001$) holding ranks from regional to international champion, a prevalence of $PWC_{170/kg}$ by 12.64% ($p<0.001$) in males was shown. Separate comparison of swimmers taking into account their ranks showed significantly greater values of $PWC_{170/kg}$ in nationally ranked male swimmers only (average age 16.35±0.51 years and 15.12±0.39 years) by 11.27% ($p=0.034$).

Our earlier studies also showed that the $PWC_{170/kg}$ in male international and national swimming champions was greater than in female swimmers with similar ranks by 15.6% ($p<0.05$), and in male nationally ranked swimmers by 17.3% ($p=0.001$) respectively [17].

Thus, available sporadic research devoted to gender differences in swimmers indicate the higher levels of haematological parameters, VO_2 max, peak anaerobic power, as well as systolic and diastolic blood pressure in men and boys, complement the idea of gender differences in a particular contingent of athletes [22, 12].

Conclusions

A comparison of 86 male and 42 female swimmers with sports qualifications from first-class athlete to Master of Sports International Class, who differed by age and training experience, showed no significant differences in HRV and central hemodynamic parameters except for $PWC_{170/kg}$, which was 12.64 % higher in males ($p<0.001$). There were no significant differences between all studied indices in 38 male and 9 female swimmers with sports qualifications Master of Sports and Master of Sports International Class, with no differences in age or training experience. Comparison of 28 male and 16 female swimmers with sports qualification Candidate for Master of Sports, not differing by age and training experience showed no significant differences in HRV and central hemodynamic parameters, except for $PWC_{170/kg}$, which was greater in males by 11.27 % ($p=0.034$). In 22 male and 17 female swimmers with sports qualification first-class athlete, not differing by age (males have greater training experience) there were no differences between all studied indices.

We once again show that in athletes, in the presence of strictly homogeneous comparison groups, taking into account the type of sport, sport qualification, competitive distance (in swimming, athletics, rowing, etc.), age, and training experience there are no differences in parameters of heart rate variability and central hemodynamics.

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Conflict of interest

The authors declare that there is no conflict

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