

Effect of the training process of high-class and elite sprint swimmers of both genders on the state of the autonomic nervous system, central hemodynamics and physical working capacity

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Purpose: to investigate the influence of the training process of high-class and elite sprint swimmers of both genders on the parameters of the autonomic nervous system, central hemodynamics and physical working capacity.

Material & Methods: in the preparatory period of the training process, 145 sprint swimmers (56 females and 89 males) with sports qualifications from CMS (high-class swimmers) to MS-MSIC (elite swimmers) were examined, of which 56 sprint swimmers (31 females and 25 males) in 2006 and 89 sprint swimmers in 2021 (25 females and 64 males). To assess the autonomic regulation of cardiac activity time- and frequency domain methods of HRV analysis were used. Central hemodynamic parameters were examined by an automated tetrapolar rheography. Physical working capacity was measured according to a common technique on a cycling ergometer using a submaximal PWC_{170} test and calculating the relative value of physical working capacity, i.e. $PWC_{170/kg}$.

Results: comparison of the studied parameters in sprint swimmers examined in 2006 and 2021 showed a significant decrease in $PWC_{170/kg}$ in present-day high-class sprint swimmers with sports qualification CMS (both females and males), by 23.84%, ($p=0.0003$) and 12.68% ($p=0.018$), respectively, and in elite male swimmers with sports qualifications MS-MSIC by 9.46% ($p=0.017$), as well as a downward trend in elite female swimmers with sports qualifications MS-MSIC by 18.28% ($p=0.154$). Differences in HRV and central hemodynamics parameters were statistically insignificant.

Conclusions: in present-day high-class female swimmers, the predominance of the sympathetic arm of the ANS was revealed, the value of $PWC_{170/kg}$ was 23.84% ($p=0.0003$) lower than in female swimmers of the same level in 2006. There were no significant differences between all the studied indices of elite female swimmers in 2021 and the indices of female swimmers of the same level in 2006. In present-day elite male swimmers and high-class male swimmers, the value of $PWC_{170/kg}$ was lower, respectively, by 9.46% ($p=0.017$) and 12.68% ($p=0.018$) than in swimmers of the same level in 2006. A significant decrease in the functional state of modern swimmers-sprinters of both genders against an earlier achievement of qualification standards than their peers in 2006 may be due to a change in the modern methodology of the training process aimed at reducing the training load in the zone of development of general endurance (aerobic orientation) by increasing the load of speed and power (anaerobic) orientation.

Key words: high-class and elite swimmers of both genders, heart rate



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variability, central hemodynamics, physical working capacity.

Анотація

Євген Михалюк, Єгор Гороховський. Вплив тренувального процесу висококласних та елітних плавців-спринтерів обох статей на стан автономної нервової системи, центральну гемодинаміку та фізичну працездатність. Мета: дослідити вплив тренувального процесу висококласних та елітних плавців-спринтерів обох статей на показники автономної нервової системи, центральної гемодинаміки та фізичну працездатність.

Матеріал і методи: обстежено 145 плавців-спринтерів (56 жінок та 89 чоловіків) рівня від КМС до МС-МСМК у підготовчому періоді тренувального процесу, з них у 2006 році 56 плавців-спринтерів (31 жінка та 25 чоловіків) та у 2021 році 89 плавців-спринтерів (25 жінок та 64 чоловіки). Для аналізу вегетативної регуляції серцевої діяльності використовували часові та спектральні показники ВСР. Центральну гемодинаміку вивчали методом автоматичної тетраполярної реографії. Визначення фізичної працездатності здійснювали за загальноприйнятою методикою на велоергометрі з використанням субмаксимального тесту PWC_{170} . **Результати:** порівняння досліджуваних показників у плавців-спринтерів, обстежених у 2006 та 2021 роках, показало достовірне зниження $PWC_{170/кг}$ у сучасних висококласних плавців-спринтерів кваліфікації КМС (як жінок, так і чоловіків), відповідно на 23,84% ($p=0,0003$) та 12,68% ($p=0,018$), та елітних плавців рівня МС-МСМК на 9,46% ($p=0,017$), а також тенденцію до його зниження у елітних плавчинь рівня МС-МСМК на 18,28% ($p=0,154$). Відмінності показників ВСР та центральної гемодинаміки мали недостовірний характер.

Висновки: у сучасних плавчинь високого класу виявлено превалювання симпатичної ланки АНС, менша на 23,84% ($p=0,0003$) величина $PWC_{170/кг}$, ніж у плавчинь аналогічного рівня у 2006 році. Між усіма дослідженими показниками елітних плавчинь у 2021 році та показниками плавчинь аналогічного рівня у 2006 році були відсутні достовірні відмінності. У сучасних елітних плавців та плавців високого класу величина $PWC_{170/кг}$ була менша, відповідно на 9,46% ($p=0,017$) та 12,68% ($p=0,018$), ніж у плавців аналогічного рівня у 2006 році. Достовірне зниження функціонального стану сучасних плавців-спринтерів обох статей на тлі більш раннього досягнення кваліфікаційних нормативів, ніж у їхніх однолітків у 2006 році, може бути зумовлене зміною сучасної методики тренувального процесу, спрямованої на зменшення тренувальної роботи в зоні розвитку загальної витривалості (аеробної спрямованості) за рахунок збільшення роботи швидко-силової (анаеробної) спрямованості.

Ключові слова: плавці високого класу та елітні плавці обох статей, варіабельність серцевого ритму, центральна гемодинаміка, фізична працездатність.

Introduction

At present, it is only an exceedingly capable athlete with a specific physique, hydrodynamic qualities, the highest level of health, physical and psychic abilities, as well as technical and tactical skills can achieve Olympic-sized goals in swimming. In this regard, a well-organized system for the search and selection of especially talented athletes is crucial. Each stage of long-term sports training has its set of criteria that determine the outlook for achieving greatness in sportsmanship (Bielec & Jurak, 2019; Johnson et al., 2008; Platonov (Ed.), 2000; Rejman et al., 2018; Sałabun et al., 2022).

The development of sports swimming and the increase in sports records are determined by many factors, and methodological approaches are some of them. In chronological order, from the beginning of the 20th century to the mid-1920s, swimmers trained 2-3 times a week for 4-6 months a year. The main method of training was swimming long distances – from 400 to 3000 m evenly at an average pace (Counsilman & Counsilman, 1994). The increase in results took place mainly due to the improvement of swimming technique, which progressed rapidly in these years. At the same time, a training technique aimed at developing endurance became widespread: an increase in the volume and intensity of swimming; the emergence of elements of interval training, alternating and repeated swimming.

Since the mid-1950s, the era of interval training began in sports swimming. It was during these years that a rapid increase in the volume of swimming training began: from 500-600 km to 2400-2700 km per year by mid-1975. Foremost, the number of low-intensity swimming increases (below the level of the anaerobic threshold – AnT). Such training improved aerobic capabilities to a greater extent: aerobic capacity and economy, and to a lesser extent, anaerobic power, i.e. thus developed mainly endurance.

In the late 1970s, training loads quickly reached their maximum (record values for individual swimmers were 3800-4000 km per year). Attempts to achieve these values, and even more so to exceed them, only have caused the deterioration in the level of results (Platonov (Ed.), 2000).

Since reserves for increasing training loads due to volume were exhausted by the beginning of the 80 s, their intensity began to increase. At the same time, the total volume of swimming even slightly decreased. Swimming with strict intervals and high speeds was widely used, and the amount of work aimed at improving anaerobic capacity and

efficiency increased (Bulhakova & Platonov, 2000; Wirth et al., 2022). Thus, further progress in swimming due to the development of aerobic power has completely exhausted itself and there was a need to intensify training work.

At present, increasing aerobic capacity and efficiency can't be the main focus of sports improvement among extra-class swimmers, since the limiting load volume at the level of the AnT and in the aerobic zone, generally, has already been achieved at the initial stages of long-standing training. The search for a methodology that improves the anaerobic capabilities of leading swimmers based on a high level of development of aerobic endurance in age groups comes to the fore.

The rationale for this is the training of 800-meter runners (the time to overcome their competitive distance is comparable to the time to swim 200 meters), in which the partial volumes of anaerobic loads are approximately 2-3 times greater than the corresponding values for swimmers; for sprinters, these differences are even greater (Mykhaliuk et al., 2022; Platonov (Ed.), 2000).

Thus, a change in the modern methodology of the training process for swimmers, aimed at reducing the training work in development of general endurance (aerobic orientation) by increasing the work of the speed-strength (anaerobic) orientation, should have affected not only sports results, but also the appearance of some features of the functional state of sprint swimmers, which became the subject of study in our work.

The aim of the study is to compare the parameters characterizing the functional state of high-class and elite sprint swimmers of both genders who fulfilled requirements for sports qualifications Candidate Masters of Sports, Master of Sports and Master of Sports, International Class in 2006 and 2021.

Material and methods of research

Participants

In the preparatory period of the training process, 145 swimmers (56 females and 89 males) with sports qualifications from CMS (high-class swimmers) to MS-MSIC (elite swimmers) were examined, of which 56 swimmers (31 females and 25 males) in 2006 and 89 swimmers (25 females and 64 males) in 2021. The participants signed an informed consent form to participate in the study. Ethical consent was provided by the ethics committee of the local institution and in accordance with the Helsinki declaration.

Methods

Mathematical and spectral methods of heart rate variability (HRV) analysis were used to assess the the autonomic regulation of cardiac activity. 5-min-

ute short ECG recordings (Cardio+, Meteocol LLC, Ukraine) were used for the HRV analysis according to the International Standard ("Heart rate variability: standards of measurement", 1996).

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 haemodynamics (CH) was studied by the automated tetrapolar rheography method (Cardio+, Meteocol LLC, Ukraine). Stroke volume (SV) and cardiac output (CO), stroke volume index (SVI), cardiac index (CI), systemic vascular resistance (SVR), and systemic vascular resistance index (SVRI) were calculated (Velicka et al., 2019).

Physical working capacity was measured according to the generally accepted technique on a stationary cycle ergometer (Corival, Lode, Netherlands) using the PWC₁₇₀ submaximal test with further calculation of the relative value of physical working capacity (PWC_{170/kg}) (Marqueta et al., 2016).

Statistical analysis

Statistical analysis of the data was performed using Statistica 13 software package (StatSoft Inc.). The data reported as mean \pm SE. The unpaired two-samples t-test 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 $p < 0.05$.

Results of the study

In the first phase of the study, a comparison of the indicators characterizing functional state of high-class female sprint swimmers ($n=13$, average age 15.6 ± 0.3 years, swimming experience 6.2 ± 0.4 years)), examined in 2006 (Mykhaliuk, 2006) and 16 swimmers of similar sports qualification (average age 15.1 ± 0.40 years, swimming experience 7.4 ± 0.44 years) examined in 2021 was made (Mykhaliuk et al., 2020; Mykhaliuk et al., 2021a; Mykhaliuk et al., 2021b).

Analysis of the temporal and spectral parameters of heart rate variability (HRV), characterizing the state of the autonomic nervous system (ANS), revealed the prevalence of the parasympathetic arm

of the ANS in female swimmers with sports qualification CMS in 2006. Thus, the Mo value, indicating the level of functioning of the cardiovascular system, was 0.996 ± 0.044 s, AMo/D – an indicator that determines the ratio of sympathetic and parasympathetic regulation of cardiac activity – $56.7 \pm 8.0\%/s$, ARI – an indicator allowing to assess the autonomic balance – 2.054 ± 0.245 $1/s^2$, SI – stress index, reflecting the degree of centralization of heart rate control – 30.08 ± 4.05 relative units (r. u.), HF – high-frequency component, reflecting vagal control of heart rate – 738.0 ± 190.1 ms^2 , LF/HF – index for the sympathovagal balance – 0.853 ± 0.341 r. u.

The average values of central hemodynamic parameters were represented by heart rate (HR), cardiac index (CI) and systemic vascular resistance index (SRVI) and corresponded to 57.8 ± 1.8 bpm^{-1} , 2.737 ± 0.093 $l \cdot min^{-1} \cdot m^{-2}$ and 28.73 ± 1.07 r. u., respectively. The CI value corresponded to the hypokinetic type of hemodynamics (TH). The percentage ratio of THs was presented as: 61.5%:38.5%:0%, respectively, hypokinetic, eukinetic and hyperkinetic TH, i. e., there was a tendency to the predominance of the hypokinetic TH over the eukinetic TH ($p=0.419$) and the absence of female athletes with a hyperkinetic TH. The $PWC_{170/kg}$ value was at a high level – 19.25 ± 0.86 $kgm \cdot min^{-1} \cdot kg^{-2}$ (Fig. 1 A).

The results obtained in 2021 (Mykhaliuk et al., 2020; Mykhaliuk et al., 2021a; Mykhaliuk et al., 2021b) in 16 female athletes with the same sports qualification showed that Mo was 0.872 ± 0.037 s, AMo/D – $88.12 \pm 15.18\%/s$, ARI – 3.104 ± 0.359 $1/s^2$, SI – 53.73 ± 9.41 r. u., HF – 337.8 ± 47.2 ms^2 , LF/HF – 1.674 ± 0.331 r. u. The obtained results of the analysis of temporal and spectral parameters of HRV reveal the tendency for the predominance of the sympathetic arm of the ANS. This is confirmed by the value of HR, which was 61.4 ± 2.9 bpm^{-1} . The integral indicator of central hemodynamics (CI) was 3.021 ± 0.11 $l \cdot min^{-1} \cdot m^{-2}$, which corresponds to eukinetic TH, and SVRI was 27.19 ± 1.31 r. u. The percentage ratio of THs was presented as: 25.0%:62.5%:12.5%, respectively, hypokinetic, eukinetic and hyperkinetic TH, which indicates a trend towards the predominance of eukinetic against hypokinetic TH ($p=0.204$) and confirms the average value of CI (Fig. 1 A).

A comparison of results obtained in high-class female swimmers, examined in 2006 (Mykhaliuk, 2006) and 2021 (Mykhaliuk et al., 2020; Mykhaliuk et al., 2021a, 2021b) indicates that present-day swimmers were on average 0.5 years ($p=0.345$) younger, started swimming training 1.2 years ($p=0.08$) earlier, had no differences in body length, and had insignificantly greater body weight ($p=0.152$). For HRV parameters, Mo was significantly less by 14.22% ($p=0.044$), ARI – greater by 51.1% ($p=0.029$), SI by 78.6% ($p=0.048$) and the upward trend in AMo/D by 55.38% ($p=0.108$) was revealed. Among the spectral parameters of HRV

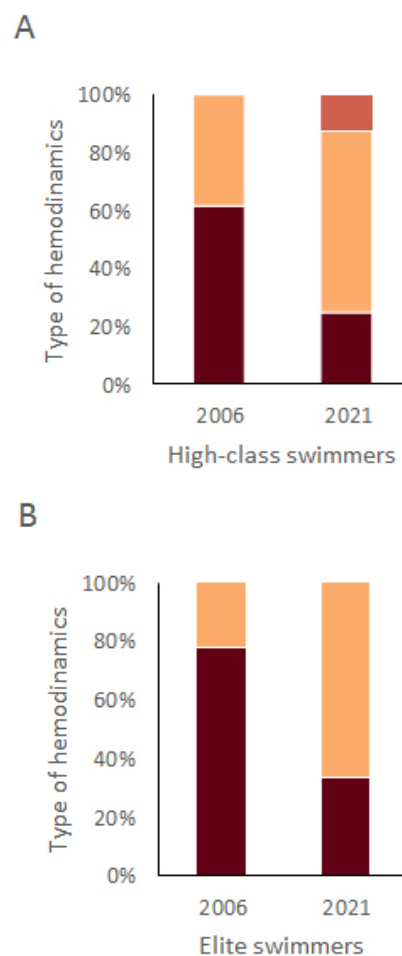


Fig. 1. The percentage ratio of THs in high-class (A) and elite (B) female swimmers in 2006 and 2021

in present-day female swimmers, the HF component is significantly less by 54.23% ($p=0.033$) and there is an upward trend in LF/HF ratio by 96.25% ($p=0.104$). From the side of central hemodynamics, these swimmers had an insignificantly higher heart rate by 6.22% ($p=0.327$) and CI by 10.4% ($p=0.075$).

Significantly lower values were revealed in the relative value of physical working capacity by 23.84% ($p=0.0003$). Thus, in present-day high-class female swimmers, it was revealed the predominance of the sympathetic arm of the ANS, physiologically less favorable eukinetic TH, and, which is important, a significantly lower value of $PWC_{170/kg}$ by 23.84% ($p=0.0003$) (Fig 2 A).

When comparing the studied indicators of elite female swimmers in 2006 (Mykhaliuk, 2006) and 2021 (Mykhaliuk et al., 2020; Mykhaliuk et al., 2021a, 2021b), it was revealed that in 18 female swimmers with these sports qualifications examined in 2006 (average age 21.0 ± 1.4 years, swimming experience 11.3 ± 1.4 years, body length – 175.0 ± 0.9 cm, body weight – 61.5 ± 0.9 kg) Mo

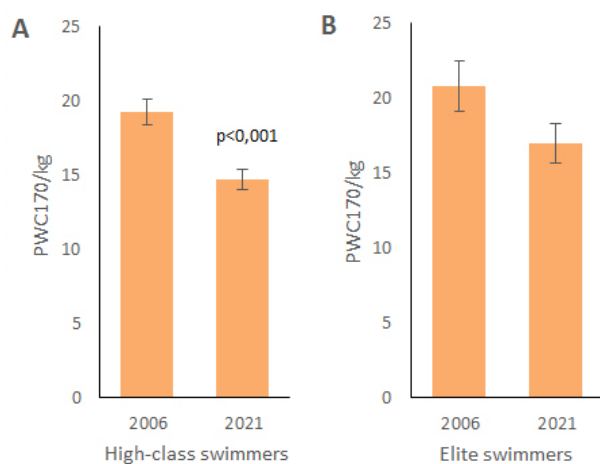


Fig. 2. The physical working capacity of high-class (A) and elite (B) female swimmers examined in 2006 and 2021

was 1.022 ± 0.032 s, AMo/D – 105.2 ± 20.9 %/s, ARI – 2.831 ± 0.418 1/s², SI – 55.74 ± 12.75 r. u., HF – 652.6 ± 148.2 ms², LF/HF – 1.054 ± 0.344 r. u. From the central hemodynamic parameters, HR was 54.3 ± 1.9 bpm⁻¹, CI – 2.555 ± 0.087 l·min⁻¹·m⁻², which corresponds to hypokinetic TH, SVRI – 30.77 ± 1.0 r. u. The percentage ratio of THs is presented as: 77.8%:22.2%:0%, respectively, hypokinetic, eukinetic and hyperkinetic TH, i. e. these swimmers showed a tendency to the predominance of hypokinetic TH ($p=0.392$) and the absence of athletes with hyperkinetic TH. The average value of $PWC_{170/kg}$ was 20.78 ± 1.70 kgm·min⁻¹·kg⁻¹.

Comparison of the studied indicators with the parameters of elite female swimmers ($n=9$) in 2021 (Mykhaliuk et al., 2020) showed that age and swimming experience were insignificantly less by 3.6 years ($p=0.109$), and 1.6 years ($p=0.461$), respectively, than in female swimmers examined in 2006. The elite female swimmers examined in 2006 had a shorter body length by 3.7 cm ($p=0.08$), but greater by 2.1 kg body weight ($p=0.302$), these differences did not reach the threshold of statistical significance, and were of a trend nature.

From the HRV parameters, there was a downward trend in Mo ($p=0.116$), AMo/D ($p=0.533$), SI ($p=0.824$) and an upward trend in ARI ($p=0.873$). For the spectral components of HRV, there was a downward trend in the HF component ($p=0.793$) and an upward trend in the sympathovagal balance index ($p=0.993$), i. e. temporal and spectral parameters of HRV attest to a trend towards the predominance of the sympathetic arm of the ANS.

For central hemodynamic parameters in present-day female swimmers, a significant increase in CI by 16.6% ($p=0.007$) was found, with 10.9% ($p=0.049$) lower values of SVRI and an upward trend in HR by 12.33% ($p=0.09$). The percentage ratio of THs was presented as 33.33%:66.67%:0%, re-

spectively, hypokinetic, eukinetic and hyperkinetic TH, i.e. there was a tendency to the predominance of eukinetic TH ($p=0.343$) and the absence of female swimmers with hyperkinetic TH (Fig. 1 B). The relative value of physical working capacity in present-day female swimmers with sports qualifications MS-MSIC was 18.28% less ($p=0.154$), but this decrease did not reach the threshold of statistical significance (Fig. 2 B).

The relative value of physical working capacity in present-day elite female swimmers was 18.28% less ($p=0.154$), but this decrease did not reach the threshold of statistical significance (Fig. 2 B).

Of scientific interest is the question of comparing the parameters of heart rate variability, central hemodynamics, and physical performance in male swimmers for the specified period in 2006 and 2021. Anthropometric measurements, HRV parameters and physical working capacity values were compared between a group of high-class male swimmers ($n=13$) examined in 2006 (Mykhaliuk, 2006) and 28 swimmers with the same sports qualification, examined in 2021 (Mykhaliuk et al., 2020; Mykhaliuk et al., 2021a, 2021b).

Age, swimming experience and body weight of present-day high-class male swimmers tended to decrease by 0.9 kg ($p=0.267$), 0.6 years ($p=0.330$) and 2 kg ($p=0.273$), respectively, while body length was significantly less by 3.8 cm ($p=0.004$). For the temporal parameters of HRV in present-day male swimmers was revealed a lower value of AMo/D (99.6 ± 12.83 vs. 105.6 ± 7.2 %/s, $p=0.788$), ARI (3.111 ± 0.302 1/s² vs. 3.228 ± 0.362 , $p=0.819$) and SI (57.82 ± 8.38 vs. 58.85 ± 10.38 r. u., $p=0.942$). Although these changes were insignificant, there is a tendency for the parasympathetic influences of the ANS to prevail. For central hemodynamic parameters, there was a downward trend in CI value (2.878 ± 0.085 vs. 02 relative units, $p=0.501$) and an upward trend in SVRI (29.43 ± 0.96 vs. 28.36 ± 1.02 r. u., $p=0.501$). The ratio of THs in male swimmers in 2006 (Mykhaliuk, 2006) was: 46.2%:38.5%:15.3%, respectively, hypokinetic, eukinetic, hyperkinetic THs, i. e. a trend towards an increase in hypokinetic TH in relation to eukinetic TH ($p=0.797$) and hyperkinetic TH ($p=0.436$) was found. In present-day male swimmers, the TH ratio was as follows: 39.3%:53.6%:7.1%, respectively, hypokinetic, eukinetic, hyperkinetic TH, i. e. a trend towards an increase in eukinetic TH in relation to hypokinetic TH ($p=0.470$) and hyperkinetic TH ($p=0.225$) was found (Fig. 3 A). Summarizing the results of comparison of central hemodynamics parameters, it can be said that in 2006, among high-class male swimmers, a tendency to the predominance of hypokinetic TH was found; in 2021 – a tendency to the prevalence of eukinetic TH. The value of physical working capacity in present-day male swimmers was 16.53 ± 0.51 kgm·min⁻¹·kg⁻¹, which is 12.68% less than in male swimmers examined in 2006 ($p=0.018$) (Fig. 4 A).

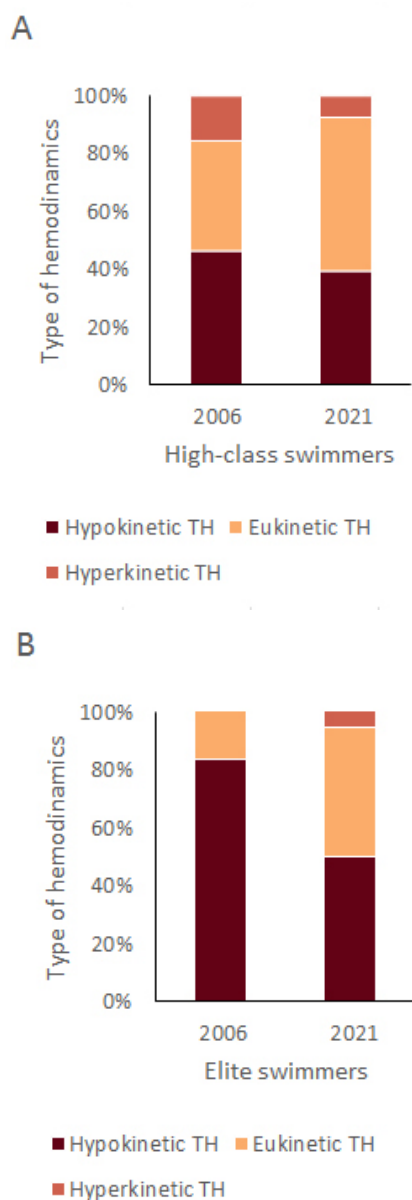


Fig. 3. The percentage ratio of THs in high-class (A) and elite (B) male swimmers examined in 2006 and 2021

Similar comparisons conducted between 36 elite male swimmers in 2021 and 12 male swimmers of the same skill level in 2006 showed the following: swimmers examined in 2021 were 0.7 years younger ($p=0.412$), had almost the same swimming experience (10.4 ± 0.44 vs. 10.3 ± 0.8 years, $p=0.911$), shorter body length (186.6 ± 1.23 vs. 188.1 ± 2.1 cm, $p=0.547$) and body weight (77.2 ± 1.36 vs. 78.0 ± 3.9 kg, $p=0.805$). Analysis of temporal parameters of HRV revealed in swimmers 2020-2021 a trend towards a decrease in Mo (0.976 ± 0.03 vs. 1.017 ± 0.028 s, $p=0.457$) and an increase in ARI ($2,734\pm 0,202$ против $2,700\pm 0,520$ $1/s^2$, $p=0,941$). These data indirectly demonstrate the predominance of the sympathetic arm of the ANS. From the part of central hemodynamic parameters, the cardiac index was significantly

higher (2.795 ± 0.059 vs. 2.550 ± 0.092 $l\cdot min^{-1}\cdot m^{-2}$, $p=0.039$); in 2006 it corresponded to hypokinetic TH, and in 2021 – to eukinetic TH. The ratio of THs in 2006 was as follows: 83.3%:16.7%:0%; respectively, hypokinetic, eukinetic and hyperkinetic TH, i. e. **hypokinetic TH significantly prevailed over eukinetic TH** ($p=0.05$) and there were no swimmers with hyperkinetic TH, which confirms the average CI values. In 2021, the ratio of THs is presented as 50.0%: 44.4%: 5.6%; respectively, hypokinetic, eukinetic and hyperkinetic TH (Fig. 3 B). In doing so, a tendency for the prevalence of hypokinetic TH over eukinetic ($p=0.744$) and hyperkinetic THs ($p=0.872$) was revealed. The physical working capacity of swimmers examined in 2021 was 18.37 ± 0.38 $kgm\cdot min^{-1}\cdot kg^{-1}$ which is significantly less by 9.46% ($p=0.017$) than that of swimmers examined in 2006 (Fig. 4 B).

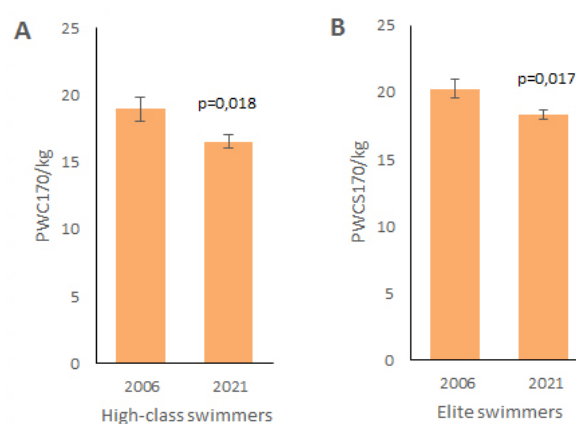


Fig. 4. The physical working capacity of high-class (A) and elite (B) male swimmers examined in 2006 and 2021

Due to the insufficient statistical power of the study, the patterns we obtained were often trends, namely, present-day elite male swimmers had a physiologically less favorable circulatory type (eukinetic), the predominance of the sympathetic arm of the ANS, a significantly lower value of physical working capacity by 9.46% ($p=0.017$), however, with the same training experience and anthropometric measurements, and gained the MS-MSIC sports titles 0.7 years earlier.

Discussion

Regarding sports medicine and sports training physiology, a substantial change in the functional state and training of highly qualified swimmers is of definite interest. Thus, in high-class female sprint swimmers in 2021 was revealed a relatively early beginning of the training process and, obviously, a longer swimming experience, a tendency to increase body weight, and also, a deterioration in many parameters characterizing their functional state: the prevalence of the sympathetic division of the ANS, an increase in resting heart rate, the presence of less physiologically beneficial eukinetic TH and a significant decrease in physical perfor-

mance. Despite the apparent deterioration in the functional state, this allowed the female swimmers of 2021 to fulfill the requirements for sports qualification CMS at sprint distances in swimming earlier than the female athletes did in 2006.

As for the present-day elite female swimmers, they reached their personal results and, accordingly, sports qualifications (MS and MSIC) earlier in age, and, no less important, for a lesser training experience compared to the swimmers of 2006. They showed some increase in the sympathetic division of the ANS; a greater resting heart rate; a less beneficial, more common eukinetic TH, and a statistically insignificant lower relative value of physical working capacity.

As we assume, the probable reason for the identified patterns in the period of 2006-2021 in swimming are changes regarding the methodology of the training process associated with the earlier beginning of swimming training, a decrease in aerobic physical loads, due to an increase in speed-strength physical loads, which led to a tendency for the predominance of the sympathetic arm of the ANS, high values of resting heart rate, less physiologically beneficial eukinetic TH and a tendency to decrease in the relative value of physical working capacity, and in high-class athletes – to its significant decrease.

Similar comparisons among high-class male swimmers showed that the age, swimming experience and body weight of present-day swimmers followed a downward trend, respectively, by 0.9 kg ($p=0.267$), 0.6 years ($p=0.330$) and 2 kg ($p=0.273$), while the body length was significantly less by 3.8 cm ($p=0.004$). They tend to the predominance of parasympathetic influences of the ANS, a tendency to the prevalence of eukinetic TH, while in 2006 there was a tendency to the prevalence of physiologically more beneficial hypokinetic TH. In addition, the physical working capacity of present-day swimmers was 12.68% less than that of swimmers examined in 2006 ($p=0.018$).

Elite male swimmers in 2021 reached their sports titles 0.7 years earlier, with the same training experience. They practically did not differ in anthropometric parameters. However, they showed a tendency towards the prevalence of the less beneficial sympathetic arm of the ANS, the physiologically less beneficial eukinetic TH and by 9.46% significantly lower values of physical working capacity ($p=0.016$) than the swimmers of 2006.

It should be noted that in discussions with swimming coaches who have the title of "Merited Coach of Ukraine", and undoubtedly having a long experience of working with high-class athletes, we have raised the question of changing the methodology of the training process for sprint swimmers over the past 15 years. The coaches confirmed our assumptions about changing the training methodol-

ogy for sprint swimmers, which consisted in reducing the amount of training work associated with the total amount of aerobic load by increasing the cyclic work of maximum power with the development of the quality of speed and strength. Naturally, after such training loads of a predominantly anaerobic-glycolytic orientation, one should not expect bradycardia, the predominance of parasympathetic influences of the ANS, hypokinetic TH and a significant increase in physical performance. Since such training of sprint swimmers contributed to the progression of sports results in a shorter time, we consider it reasonable and truly useful to concentrate all the efforts of the training process on the development of the speed-strength qualities of swimmers.

Conclusion

1. In present-day high-class female swimmers, the predominance of the sympathetic arm of the ANS was revealed, the value of PWC_{170/kg} was 23.84% ($p=0.0003$) lower than in female swimmers of the same level in 2006. There were no significant differences between all the studied indices of elite female swimmers in 2021 and the indices of female swimmers of the same level in 2006.
2. In present-day elite male swimmers and high-class male swimmers, the value of PWC_{170/kg} was lower, respectively, by 9.46% ($p=0.017$) and 12.68% ($p=0.018$) than in swimmers of the same level in 2006.
3. A significant decrease in the functional state of modern swimmers-sprinters of both genders against an earlier achievement of qualification standards than their peers in 2006 may be due to a change in the modern methodology of the training process aimed at reducing the training load in the zone of development of general endurance (aerobic orientation) by increasing the load of speed and power (anaerobic) orientation.

Author's contribution

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

Conflicts of Interests

The authors declare no conflict of interest.

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