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The Effectiveness of Pilates in Improving Autonomic Regulation in Female Athletes of Complex Coordination Sports

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Abstract

Purpose: To assess the impact of the developed Pilates program on the improvement of physical qualities and the functional state of the autonomic nervous system in female athletes of complex coordination sports in the preparatory period.

Material and methods. The analysis of heart rate variability was utilized for female athletes of complex coordination sports at baseline and after 3 months of training in preparatory period. 36 female athletes of complex coordination sports (sports aerobics, n=26 and sports acrobatics) participated in the pedagogical experiment during the specialized basic training phase. The average age of the studied female athletes was 15.7 ± 0.5 years. The primary group comprised 18 athletes of complex coordination sports engaged in a regimen aimed at enhancing the functional condition of the autonomic nervous system (Pilates group). In contrast, the control group comprised 18 female athletes following the training program of yoga. The number of Pilates classes in the main group and yoga in the control group was the same and amounted to 36 classes.

Results: at the end of the pedagogical experiment comparison of heart rate variability parameters revealed to significant differences between the main and control groups of female athletes of complex coordination sports for nearly all parameters. In the examined main group athletes of complex coordination sports the standard deviation of mean values (SDNN) was superior by 8.10 ms ($p<0.001$, $t=6,15$) compared to the control group. Additionally, the square root of the sum of the squares of differences in consecutive pairs of N-N intervals (RMSSD) showed improvement by 8.96 ms ($p<0.001$, $t=5,94$), the total power of regulatory systems (TP) was better by 298.40 ms² ($p<0.001$, $t=8,97$), the very low-frequency component of the spectrum (VLF) was superior by 47.00 ms² ($p<0.05$, $t=2,15$), the high-frequency component of the spectrum demonstrated improvement by 176.03 ms² ($p<0.001$, $t=4,66$), the LF/HF ratio was better by 1.18 units ($p<0.01$, $t=3,14$), the index of centralization (IC) was superior by 1.11 unit ($p<0.01$, $t=3,02$), the amplitude of mode (Amo) exhibited improvement by 18.00% ($p<0.01$, $t=5,05$), the stress index was superior by 133.97 units ($p<0.001$, $t=5,88$), the index of regulatory system activity was better by 1.79 units ($p<0.01$, $t=3,22$), the percentage contribution of the low-frequency component of the spectrum (LF) was improved by 12.70% ($p<0.001$, $t=3,97$), and the high-frequency component of the spectrum (HF) was superior by 9.74% ($p<0.001$, $t=3,53$).

Conclusions: the results show that the inclusion of toning and relaxing Pilates techniques during the pedagogical experiment had a positive effect on improving flexibility, strength, balance, coordination, and increasing the functional state of the autonomic nervous system in women of complex coordination sports in the preparatory period of specialized basic training.

Keywords: heart rate variability, preparedness, breathing exercises, athletes, women.

Ефективність занять пілатесом у покращенні вегетативної регуляції у спортсменок складнокоординаційних видів спорту

Мета: Оцінити вплив розробленої програми пілатесу на вдосконалення фізичних якостей та функціональний стан вегетативної нервової системи у спортсменок складнокоординаційних видів спорту в підготовчому періоді.

Матеріал і методи: Аналіз варіабельності серцевого ритму використовували у спортсменок складнокоординаційних видів спорту на початковому етапі та через 3 місяці тренувань у підготовчому періоді. У педагогічному експерименті на етапі спеціалізованої базової підготовки брали участь 36 спортсменок складнокоординаційних видів спорту (спортивна аеробіка, n=26 та спортивна акробатика). Середній вік досліджуваних спортсменок становив 15,7 ± 0,5 року. Основну групу склали 18 спортсменок складнокоординаційних видів спорту, які займалися за режимом, спрямованим на підвищення функціонального стану вегетативної нервової системи (група пілатесу). Натомість контрольна група складалася з 18 спортсменок, які займалися програмою йоги. Кількість занять пілатесом в основній групі та йогою в контрольній групі була однаковою і становила 36 занять.

Результати: Наприкінці педагогічного експерименту порівняння показників варіабельності серцевого ритму виявило достовірні відмінності між основною та контрольною групами спортсменок складнокоординаційних видів спорту майже за всіма параметрами. В обстежених спортсменів основної групи складнокоординаційних видів спорту стандартне відхилення середніх значень (SDNN) було вищим на 8,10 мс ($p<0,001$, $t=6,15$) порівняно з контрольною групою. Крім того, квадратний корінь суми квадратів відмінностей між послідовними парами інтервалів N-N (RMSSD) показав покращення на 8,96 мс ($p<0,001$, $t=5,94$), загальна потужність регуляторних систем (TP) була кращою на 298,40 мс² ($p<0,001$, $t=8,97$), дуже

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низькочастотний компонент спектра (VLF) був вищим на 47,00 мс² (p<0,05, t=2,15), високочастотний компонент спектра демонстрував покращення на 176,03 мс² (p<0,001, t=4,66), співвідношення LF/HF було краще на 1,18 одиниць (p<0,01, t=3,14), індекс централізації (IC) був вищим на 1,11 одиниць (p<0,01, t=3,02), амплітуда моди (Amo) показала покращення на 18,00% (p<0,01, t=5,05), стрес-індекс був вищим на 133,97 одиниць (p<0,001, t=5,88), індекс активності регуляторної системи був кращим на 1,79 одиниць (p<0,01, t=3,22), відсотковий внесок низькочастотного компонента спектра (LF) покращився на 12,70% (p<0,001, t=3,97), а високочастотний компонент спектра (HF) був вищим на 9,74% (p<0,001, t=3,53).

Висновки: Результати свідчать, що включення тонізуючих та релаксуючих технік пілатесу під час педагогічного експерименту позитивно вплинуло на вдосконалення гнучкості, сили, балансу, координації, підвищення функціонального стану автономної нервової системи у жінок складнокоординаційних видів спорту у підготовчому періоді спеціалізованої базової підготовки.

Ключові слова: варіабельність серцевого ритму, підготовленість, дихальні вправи, спортсмени, жінки.

Introduction

In the theory and methodology of sports training, six main types of training of athletes are distinguished: technical, tactical, physical, theoretical, psychological and integral, which are closely related. The multidimensional combination of various types of training and, above all, the combination of technical and physical is one of the leading trends in the development of the modern system of multi-year improvement of athletes in complex coordination sports [1, 16].

Improving sportsmanship in complex coordination sports becomes special importance in connection with the requirements for the entire process of training athletes, which are related to the specifics of activities in sports with complex coordination. Along with other types of sports training, physical and functional training should be aimed at achieving highly competitive result, taking into account the individual characteristics of each athlete and the chosen type of sports activity [19].

Autonomous (vegetative) regulation, also known as autonomic regulation, pertains to the intrinsic ability of the nervous system to maintain internal homeostasis and respond to environmental changes without conscious effort. This regulatory mechanism is governed by the autonomic nervous system (ANS), which comprises sympathetic and parasympathetic divisions.

The relevance of studying vegetative regulation in female athletes of complex coordination sports lies in its potential to enhance performance and well-being. Understanding the intricacies of the autonomic nervous system's influence on athletes during sports can offer valuable insights into optimizing training methodologies and recovery strategies. Moreover, investigating vegetative regulation may provide a scientific basis for tailoring individualized training programs to improve athletes' adaptability to the physical and mental demands of female athletes of complex coordination sports. This research has the potential not only to advance the scientific understanding of physiological responses in complex coordination sports but also to contribute practical implications for coaches, trainers, and athletes aiming to achieve peak performance and overall health in this demanding discipline [7, 13, 20].

The importance of maintaining a balance between the sympathetic and parasympathetic nervous systems is crucial for female athletes of complex coordination sports. These two branches of the autonomic nervous system play a pivotal role in regulating physiological responses and maintaining overall well-being [6].

Achieving an optimal balance between sympathetic and parasympathetic activation is essential for sports performance. The sympathetic nervous system is associated with the "fight or flight" response, promoting alertness and energy mobilization. In contrast, the parasympathetic nervous system promotes relaxation, recovery, and energy conservation. Striking the right balance ensures that athletes can effectively respond to the physical and mental demands of complex coordination sports while also facilitating recovery during rest periods [3].

Imbalances in autonomic regulation can lead to the maladaptation of the body by reducing the athlete's reserve capabilities. An overactivation of the sympathetic system may result in increased stress, fatigue, and a heightened risk of injury. Conversely, an overactive parasympathetic system may lead to sluggishness and reduced readiness for dynamic athletic movements [5, 11].

Therefore, understanding and monitoring the balance between these two systems in female athletes of complex coordination sports become crucial for optimizing training adaptations, enhancing recovery, and preventing burnout or overtraining. Strategies aimed at modulating the autonomic balance, such as specific training interventions, recovery techniques, and stress management, can contribute to the overall success and well-being of athletes of complex coordination sports.

At present, the Pilates method is widely utilized in health clinics, where professionals employ it to facilitate voluntary heart rate variability, body control, enhance posture, stabilize core muscles during dynamic movements, and promote both physical and mental vitality [4, 8, 9]. Despite its widespread use across diverse populations, including female subjects [2, 14, 15], the applicability of the Pilates method remains unclear.

The Pilates system is aimed at improving the work of the musculoskeletal system, cardiovascular and lymphatic systems, strengthening the stabilizer muscles that support the spine, as well as improving the sense of balance and one's body in space, coordination, strength and muscular endurance. teaching women in complex coordination sports to move harmoniously and elegantly. The main feature of the Pilates system is that during the exercises, deep-seated stabilizer muscles are activated, such as the transversus abdominis, pelvic floor muscles, and multi-section muscles of the spine. This distinguishes it from most other types of fitness, as such training contributes to the balanced development of the body, the physical qualities of women in complex coordination sports, and the improvement of appearance and health. The classes use a variety of exercises such as inclines, turns, twists, lunges in different directions, squats, push-ups, back rolls, balance exercises, as well as exercises for the balanced development of the abdominal and back muscles. Smoothness and accuracy of execution help to avoid tearing of muscle tissue, shock loads on joints and muscle overload.

The limited number of studies that systematically evaluate the influence of the Pilates method on physical qualities and autonomic modulation of the heart in women involved in complex coordination sports, and the lack of standardized methodologies limit its use in sports.

So, the aim of the study is to assess the impact of the developed Pilates program on the improvement of physical

qualities and the functional state of the autonomic nervous system in female athletes of complex coordination sports in the preparatory period.

Material and Methods

Participants. 36 female athletes of complex coordination sports (sports aerobics, n=26 and sports acrobatics, n=10) participated in the pedagogical experiment during the specialized basic training phase in the preparatory period. The average age of the studied female athletes was 15.7 ± 0.5 years. The primary group comprised 18 athletes of complex coordination sports engaged in a regimen aimed at enhancing the functional condition of the autonomic nervous system (Pilates group). In contrast, the control group comprised 18 female athletes following the training program of yoga. The number of Pilates classes in the main group and yoga in the control group was the same and amounted to 36 classes. All participants provided written informed consent to participate in the study and were informed about the purpose and procedures of the testing, as well as the possibility of withdrawing consent at any time for any reason. This study was approved by the Bioethics Committee for Clinical Research and conducted in accordance with the Declaration of Helsinki.

Research organization. The pedagogical experiment spanned a duration of three months. Both the main and control groups underwent identical structures and content for general and specific physical training, as well as technical and tactical training. The sole deviation was observed in the application of Pilates means, which were tailored individually for the female athletes of complex coordination sports in the main group. The program design incorporated considerations for the initial functional capabilities of female athletes of complex coordination sports in the main group, serving as the foundation for determining the volume and intensity of physical activities. To enhance the functional state of the autonomic nervous system in the main group's athletes, the experimental program incorporated special Pilates exercises and regulated breathing exercises that normalize the activity of the parasympathetic and sympathetic parts of the autonomic nervous system. During the selection of funds, the presence of sympathicotonia or parasympathicotonia in female athletes was taken into account.

The duration of Pilates classes and regulated breathing exercises was 3 times a week for 1 hour for three months. Each lesson included a preparatory part (10 minutes), a main part (40 minutes) and a final part (10 minutes). The intensity was varied from 40-45% to 60-70% of reserve heart rate.

The preparatory part included the following exercises: High knees, Arm swings, Torso twists, which were performed at a slow pace with an emphasis on prolonged exhalation to reduce the excitability of the sympathetic part of the autonomic nervous system. The main part of the classes consisted of Pelvic Tilts, The Hundred, Single Leg Stretch, Double Leg Stretch, Spine Stretch Forward, Pilates Ring Squats, Stability Ball Rollout, Side-Lying Leg Press with Resistance Band, Chest Expansion with Resistance Band, Teaser on Stability Ball, Swan Dive on the Pilates Barrel.

The final part of the lesson consisted of relaxation and breathing exercises: in the case of parasympathicotonia, the emphasis was on forced inhalation and breath-holding during the inhalation phase, and in the case of sympathicotonia − on prolonged slow exhalation and breath-holding during the exhalation phase. Final part included the following exercises: Cat-Cow Stretch, Seated Forward Bend, Butterfly Stretch, Hip Flexor Stretch. The complexity of the breathing exercises was adjusted according to the individual's functional ability.

During a twelve-week period, yoga sessions in control group were held thrice weekly. These sessions encompassed a variety of poses, including static, dynamic, statodynamic, relaxing, and respiratory, tailored to each participant's cardiovascular capacity. The yoga program comprised breathing exercises lasting 10 minutes, followed by 40 minutes of asanas performed in standing, sitting, and lying positions, concluding with 10 minutes of relaxation exercises in the supine position. The range of motion underwent gradual increments, starting with movements in the distal parts of the upper extremities and progressively transitioning to the proximal areas. These movements were smoothly integrated into a cohesive structure. Movement coordination with respiration synchronized the initiation of movement with the onset of inspiration, maintaining a consistent pace throughout the asana practice.

To effectively train female athletes in breathing exercises, stable sitting postures were predominantly utilized to ensure comfort and sustained attention on the muscles involved in breathing. Each session incorporated asanas from various starting positions to engage diverse muscle groups and prevent localized and general fatigue.

To assess the functional state of female athletes, analysis of temporal and spectral indicators of heart rate variability was used [17]. The following heart rate variability indicators were assessed: short-term records of RR intervals, extracting heart rate variability parameters including SDNN (standard deviation of the normal-to-normal intervals), RMSSD (square root of the mean of the squared differences between adjacent normal RR intervals), TP (total power), VLF (very low frequency), LF (low frequency), HF (high frequency), LF/HF ratio, IC (centralization index), Amo (mode amplitude), SI (stress index) and RSAI (regulatory system activity index).

The assessment of HRV parameters was conducted using the electrocardiographic system KARDIOLAB (developed by the Scientific and Technological Centre of Radio-Electronic Medical Equipment and Technologies XAI-Medica at the National Aerospace University, Kharkiv, Ukraine, with registration certificate number 6037/2007 and conformity certificate number UA-MI/2p-2765-2009).

Statistical analysis. The examination of the acquired experimental data was performed using the Statistica software for Windows (version 10.00). Before conducting the analysis, we evaluated the data for normality, homogeneity, and the presence of outliers. The distribution of the recorded data was tested using the Shapiro-Wilk test. This preliminary assessment took place prior to parametric calculations for the analysis of differences. To explore heart rate variability parameters within a group between baseline and post-intervention, a dependent T-test was applied. Independent sample t-tests were employed to compare post-intervention heart rate variability parameters between two groups of female athletes. A significance level of $p<0.05$ was considered for statistical significance.

Results

To establish the foundation for devising a program aimed at enhancing the functional state of the autonomic nervous system in female athletes of complex coordination sports, it was imperative to ascertain the characteristics of their heart rate variability indicators at the onset of the preparatory period during the specialized basic training phase (refer to Table 1).

In order to assess adaptive-compensatory reactions, the functional state of the autonomic nervous system, and the specific alterations in neurohumoral regulation resulting from the implemented experimental program, a re-evaluation of heart rate variability indicators was conducted among female

athletes of complex coordination sports belonging to both the main and control groups.

Upon a detailed examination of the heart rate variability data presented in Table 1, it was observed that the developed program of Pilates and breathing exercises had a substantial impact on reducing the regulatory system tension in female athletes of complex coordination sports within the main group. This effect was evident through a significant decrease in the stress index (SI) by 188.00 units ($p<0.001$) and the regulatory system activity index (RSAI) by 2.62 units ($p<0.001$).

In contrast, among the female athletes of complex coordination sports within the control group, the reduction in these indicators was only 53.81 ($p>0.05$) and 0.81 units ($p>0.05$), respectively, suggesting a lack of a significant influence on diminishing the activity of the sympathetic division of the autonomic nervous system.

Additionally, the prevalence of the sympathetic division in the autonomic nervous system of female athletes in the control group was further evidenced by the LF/HF ratio values. These values exhibited a marginal decrease of only 0.10 units ($p>0.05$) during the study, amounting to 2.19±0.22 units.

The standard deviation of mean values (SDNN) from 10-minute segments in the female athletes of complex coordination sports within the main group exhibited a significant increase by 8.62 ms ($p<0.001$). Similarly, the square root of the sum of the squares of differences in consecutive pairs of N–N intervals (RMSSD) saw an elevation of 10.04 ms ($p<0.001$). The total power of regulatory systems (TP) experienced a notable increase of 398.05 ms² ($p<0.001$). This increase was attributed to the elevation of the low-frequency component of the spectrum (LF) by 36.45 ms² ($p<0.05$), the high-frequency component (HF) by 190.63 ms² ($p<0.001$), and the very low-frequency component of the spectrum (VLF) by 59.97 ms² ($p<0.001$).

In the control group of female athletes of complex coordination sports, the standard deviation of mean values (SDNN) from 10-minute segments exhibited a non-significant increase of 0.88 ms ($p>0.05$). The square root of the sum of the squares of differences in consecutive pairs of N–N intervals (RMSSD) recorded an increase of 2.18 ms ($p>0.05$). The total power of regulatory systems (TP) demonstrated a significant increase of 117.79 ms² ($p<0.01$). This increase was propelled by an elevation in the low-frequency component of the spectrum (LF) by 61.00 ms² ($p<0.05$), the high-frequency component (HF) by 99.00 ms² ($p<0.05$), and a predominant increase in the very low-frequency component of the spectrum (VLF) by 16.00 ms² ($p>0,05$).

Table 1. Dynamics of indicators of heart rate variability (M ± m) in female athletes of complex coordination sports of the main group and the control group during the specialized basic training phase

Indicator	Main group (n=18)			Control group (n=18)		
	Beginning	3 months	p, t-cr	Beginning	3 months	p, t-cr
SDNN (ms)	23,58±0,91	32,20±0,97 ***	<0,001, 6,48	23,22±0,92	24,10±0,89	>0,05, 0,68
RMSSD (ms)	19,88±0,96	29,92±0,95 ***	<0,001, 7,43	18,78±0,96	20,96±0,91	>0,05, 1,64
TP (ms²)	722,55±21,00	1120,60±24,0 ***	<0,001, 12,48	704,41±19,00	822,20±23,00	<0,001, 3,94
VLF (ms²)	288,67±15,80	348,64±15,87 *	<0,01, 2,76	285,64±17,85	301,64±17,80	>0,05, 0,63
LF (ms²)	298,33±11,88	334,78±12,74	<0,05, 2,09	293,32±12,89	354,32±11,88	<0,01, 3,47
HF (ms²)	137,84±8,22	328,47±12,23 ***	<0,001, 12,93	133,44±8,27	152,44±9,21	<0,05, 2,03
LF/HF (c.u.)	2,16±0,30	1,01±0,20 **	<0,001, 3,18	2,20±0,35	2,19±0,22	>0,05, 0,02
IC (c.u.)	3,78±0,16	2,17±0,26 **	<0,001, 5,27	3,59±0,16	3,28±0,17	>0,05, 1,32
Амо (%)	79,22±2,80	58,12±2,80 ***	<0,001, 5,32	78,82±2,74	76,12±2,20	>0,05, 0,76
Si, (c.u.)	399,44±18,99	211,44±19,27 ***	<0,001, 6,94	399,22±19,21	345,41±20,27	>0,05, 1,92
Regulatory system activity index (c.u.)	6,97±0,35	4,35±0,34 ***	<0,001, 5,36	6,95±0,38	6,14±0,36	>0,05, 1,54
VLF (%)	40,87±2,14	32,90±2,14	<0,01 2,63	30,99±2,17	34,78±2,21	>0,05, 1,22
LF (%)	41,28±2,77	30,60±2,76 ***	<0,01 2,73	40,82±2,66	43,30±2,55	>0,05, 0,67
HF (%)	19,08±2,11	29,59±2,15 ***	<0,001 3,48	19,99±2,14	19,85±2,11	>0,05, 0,04

Notes: *p<0.05, **p<0.01,***p<0.001 compared with the data of the main group and the control group after 3 months

During the study in the main group of female athletes of complex coordination sports, there were statistically significant changes in the percentage contribution of individual components to the overall regulatory system activity. Specifically, the low-frequency component exhibited a significant increase by 10.68% ($p<0.001$), and the high-frequency component showed a significant increase by 10.51% ($p<0.001$). In contrast, in the control group of female athletes of complex coordination sports, no significant changes were observed in these components.

The comparison of repeated indicators of heart rate variability revealed significant differences between the main and control groups of female athletes of complex coordination sports for nearly all parameters. In the examined female athletes of complex coordination sports in the main group, the standard deviation of mean values (SDNN) from 10-minute segments was superior by 8.10 ms ($p<0.001$) compared to the control group. Additionally, the square root of the sum of the squares of differences in consecutive pairs of N-N intervals (RMSSD) showed improvement by 8.96 ms ($p<0.001$), the total power of regulatory systems (TP) was better by 298.40 ms² ($p<0.001$), the very low-frequency component of the spectrum (VLF) was superior by 47.00 ms² ($p<0.05$), the high-frequency component of the spectrum demonstrated improvement by 176.03 ms² ($p<0.001$), the sympathovagal index (LF/HF) was better by 1.18 units ($p<0.01$), the index of centralization (IC) was superior by 1.11 unit ($p<0.01$), the amplitude of mode (Amo) exhibited improvement by 18.00% ($p<0.01$), the stress index was superior by 133.97 units ($p<0.001$), the index of regulatory system activity was better by 1.79 units ($p<0.01$), the percentage contribution of the low-frequency component of the spectrum (LF) was improved by 12.70% ($p<0.001$), and the high-frequency component of the spectrum (HF) was superior by 9.74% ($p<0.001$).

Hence, among female athletes of complex coordination sports engaged in complex coordination sports in the main group, there was an evident increase in the activity of parasympathetic influences, suggesting an improvement in the adaptive capabilities of the autonomic nervous system.

Conversely, female athletes in the control group, participating in complex coordination sports, displayed an excessive influence of the sympathetic division of the autonomic nervous system during rest. This observation indicates an irrational adaptive response of the body, potentially leading to resource depletion.

Discussion

Improving the results of performances at competitions in complex coordination sports is a complex long process, which is determined by high indicators of orientation in space and time; rationality of motor actions; clear reproduction of the form of various movements of different complexity groups; level of physical and functional fitness, as well as other conditions and factors.

Among the types of training of athletes in complex coordination sports, functional training occupies an important place, which relates to its versatility, influence on aesthetic education, development of creative abilities of athletes, improvement of physical fitness, technical training. Physical training and the functional state of the autonomic nervous system require further improvement in today's conditions [10, 12].

The sympathetic division of the ANS is primarily responsible for initiating the "fight or flight" response in reaction to perceived threats or stressors. It activates physiological processes that increase heart rate, dilate bronchioles, and divert blood flow to skeletal muscles, preparing the body for action. Key neurotransmitters involved in the sympathetic response include norepinephrine and epinephrine, which bind to adrenergic receptors located throughout the body. In contrast, the parasympathetic division mediates the "rest and digest" response, promoting relaxation and conservation of energy. The balance between sympathetic and parasympathetic activity is crucial for maintaining physiological equilibrium in complex coordination sports.

To explore the impact on parasympathetic activity in this study, we examined the variation in the autonomic nervous system function value following Pilates. The findings revealed an elevation in the parasympathetic activity value in all female athletes of complex coordination sports of the main group, which may indicate an increase in the adaptive capabilities of the body.

The outcomes of our study propose that Pilates sessions lasting 60 minutes are conducive to maintaining a well-balanced control of the autonomic nervous system function in female's athletes. Furthermore, the sustained practice of Pilates may to contribute to an enhancement in ANS function over time.

Our findings demonstrate a significant modulation of autonomic nervous system activity following the Pilates intervention. Specifically, we observed changes in sympathetic and parasympathetic tone, increased parasympathetic activity, decreased sympathetic arousal. These alterations suggest a favorable impact of Pilates exercise on ANS regulation, potentially contributing to enhanced physiological balance and stress resilience.

The outcomes of our research support the viewpoint emphasized by researchers [16, 18], emphasizing the crucial importance of aligning with contemporary high-performance sports standards and accounting for the individual characteristics of the athletes. This includes a comprehensive assessment of their functional state and level of physical fitness. These findings underscore the necessity to reevaluate and modify existing training programs for sports aerobics and sports acrobatics, particularly during the specialized basic training phase.

The devised experimental program designed to enhance the functional state of the autonomic nervous system in female athletes engaged in complex coordination sports emphasizes the strategic integration of mobilization and relaxation approaches.

Therefore, through the implementation of special Pilates and breathing exercises, specific interventions were employed to modulate the activity of both the sympathetic and parasympathetic divisions of the autonomic nervous system. This strategic approach aimed to enhance the adaptive capacities of female athletes engaged in complex coordination sports, potentially mitigating the overall strain experienced by their bodies.

Certain limitations of this study warrant consideration. The sample size in the current investigation was relatively small, underscoring the need for larger-scale studies. It is recommended that future research encompasses a more extensive range of athletes, taking into account other sports. The present study exclusively focused on the evaluation of young athletes in complex coordination sports; therefore, broadening the scope to include various age groups, sports, and genders would provide a more comprehensive understanding. Additionally, to enhance the depth of analysis, future studies should consider incorporating additional parameters, such as parameters of central hemodynamics and external respiration.

Conclusions

The results show that the inclusion of toning and relaxing Pilates techniques during the pedagogical experiment had

a positive effect on improving flexibility, strength, balance, coordination, and increasing the functional state of the autonomic nervous system in women of complex coordination sports in the preparatory period of specialized basic training.

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