

Developmental features of coordination skills in young gymnasts with different types of autonomic nervous regulation

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Published online: December 30, 2024

Accepted for publication: December 15, 2024

DOI:10.7752/jpes.2024.12306

Abstract:

In the training systems for athletes across various specializations, enhancing coordination skills is crucial, particularly in sports requiring complex coordination. **Purpose.** To develop and test a methodology for improving coordination skills in 6-7-year-old girls engaged in rhythmic gymnastics, tailored to the characteristics of their autonomic nervous regulation. **Material and methods.** The study involved 40 girls (6.4 ± 1.8 years old) in their first year of rhythmic gymnastics at the initial training stage. Based on the Kerdo index, which characterizes autonomic nervous regulation types, a control group (CG, $n = 19$) was identified. These athletes followed the federal standard training program. The experimental group (EG, $n = 21$) participated in a program designed to develop coordination skills, tailored to the specific features of autonomic regulation. The methodology comprised sets of physical exercises, techniques, and methodological approaches, which were applied differentially to athletes with sympathicotonic and parasympathicotonic types of autonomic nervous regulation. In both groups, milestone assessments were performed to evaluate the development of static and dynamic coordination, as well as overall physical fitness. **Results.** Analysis of the milestone testing results revealed that in the EG, where the proposed methodology for developing coordination skills was applied, the test scores were significantly higher than those in the CG. Athletes with a sympathicotonic type of autonomic regulation achieved better results in motor coordination tests, while those with a parasympathicotonic type excelled in static coordination tests. Athletes with a higher level of coordination development also demonstrated superior results in general physical fitness tests compared to the girls in the CG. **Conclusions.** It is more effective to develop and improve coordination skills in young gymnasts by considering the identified features of their autonomic nervous regulation. This approach not only improves coordination abilities but also contributes to a higher overall level of physical fitness in the athletes.

Key Words rhythmic gymnastics, physical training, vegetative type of nervous regulation, coordination skill, physical education

Introduction

Research indicates that gymnastics is a popular sport that promotes the harmonious physical development of children (İpek Dongaz et al., 2024). Rhythmic gymnastics, a complex coordination sport, involves exercises, combinations, and the use of game tools aimed at developing speed, endurance, strength, agility, flexibility, functional abilities, and coordination skills (Barreto et al., 2023; Irwin et al., 2021; Gaspari et al., 2024). A key role in gymnastics is played by visual orientation, muscle-joint sense, vestibular and proprioceptive stability, as well as the state of the cardiorespiratory and nervous systems (Mangalam et al., 2024).

Analysis of the examination results of 6-7-year-old girls practicing rhythmic gymnastics reveals physical and psychological development characteristics that coaches should consider to create optimal conditions for the child's harmonious development. Coordination skills are crucial factors in achieving success in various sports, as highlighted by studies in table tennis (Razali et al., 2023), step aerobics (Mischenko et al., 2024), football (Vako

et al., 2024), and badminton (Donie et al., 2023). This skill is also essential in the physical education of schoolchildren (Mardiansyah et al., 2024) and in children with mental disabilities (Pavlenko et al., 2022).

Coordination abilities in 6-7-year-old gymnasts are key factors for success in the sport. These abilities involve controlling the body in space, maintaining balance, and performing complex movements with precision and consistency (Hiley et al., 2019). Developing these abilities requires regular training focused on enhancing other motor qualities such as flexibility, strength, speed, and endurance. The technique is also crucial because it helps gymnasts improve coordination, with the use of specialized exercise machines and equipment in gymnastics classes being particularly beneficial (Mischenko et al., 2020). In addition, coordination abilities encompass balance, agility, movement precision, and the capacity to adapt to new conditions.

The primary methods and techniques in gymnastics include active training games, general developmental exercises, choreographic routines, gymnastic turns, jumping, paired-group exercises, and plyometric training (Yu et al., 2024; Cabrejas et al., 2024). The use of weights is recommended when performing jumping exercises (Piazza et al., 2014). After active games and general physical training, it is recommended to include special preparatory sets of exercises that closely align with the chosen sport (Kokarev et al., 2023). In young athletes, motor acrobatic skills should be developed alongside coordination and functional abilities (Rudd et al., 2017; Biino et al., 2023). This combination ensures the achievement of high sports results in gymnastics. At the initial stage of gymnastics training, it is crucial to focus on teaching athletes the technique of the entire exercise rather than just individual components. Training should be concentrated, with sessions being lengthy, and the break between classes should not exceed 3 days (Dveyrina et al., 2024).

The development of coordination abilities in young gymnasts has unique characteristics (Monfort-Torres et al., 2024). At this age, children are primarily playful. Thus, learning occurs through games, game exercises, and relay races. Children tend to become quickly fatigued by monotonous exercises. Thus, it is important to alternate various types of activities such as physical exercises, outdoor games, and dances. Overall, the development of coordination abilities in gymnasts should be gradual and systematic, which will allow for achieving good results in the future (Dveyrina et al., 2024).

The development of coordination abilities in young gymnasts has its own characteristics (Monfort-Torres et al., 2024). At this age, children are predominantly playful, so learning occurs through games, game exercises and relay races. Children of this age quickly get tired of monotonous exercises, so it is necessary to alternate different types of activities: physical exercises, outdoor games, dances. In general, the development of coordination abilities in gymnasts of years should be gradual and systematic, which will allow achieving good results in the future (Dveyrina et al., 2024). In rhythmic gymnastics, an important role is given to the musical perception of music in children. This sport develops dance-rhythmic movements, which ensures emotional and creative development, improvement of the child's psychophysical and functional indicators (Zeng, & Zheng, 2024). Children's mastery of rhythmic gymnastics depends on many factors. One of them is the peculiarity of the autonomic innervation of the organs and systems of the child's body. It is known that the autonomic nervous system plays an important role in muscle contraction, which regulates vascular tone, hormonal supply, cardiac activity and other functional systems (Shoemaker, & Gros, 2024). The scientific literature mainly presents information on the autonomic nervous support of cardiac activity during human physical activity, which is defined as heart rate variability (Gronwald et al., 2024). The ratio of sympathetic or parasympathetic innervation of the heart is used to judge the state of the reserve capabilities of the cardiovascular system to perform physical activity. This allows for instrumental control of the athlete's training process (Liu et al., 2021). However, the literature does not sufficiently cover the issues of constructing training sessions in rhythmic gymnastics to develop coordination skills taking into account the type of vegetative innervation of the athlete's body. Using the knowledge gained on this issue will improve the efficiency of developing and improving the coordination abilities of young gymnasts, which will have a positive effect on their athletic performance.

Research aim. Based on the characteristics of the autonomic nervous regulation in 6–7-year-old girls practicing rhythmic gymnastics, a method for developing their coordination skills should be proposed and tested.

Materials and methods

The study was performed at the Children's and Youth Sports School in Osh, Kyrgyzstan. A randomized method was used to select 40 girls aged 6–7 years (6.4 ± 1.8) who were in their first year of rhythmic gymnastics. The children were divided into two groups: the control group (CG, $n = 19$) and the experimental group (EG, $n = 21$). At the start of the study, the type of autonomic regulation for all children was determined using the Kerdo index: $CI = 100 \times (1 - BP/HR)$, where BP is diastolic blood pressure (mmHg) and HR is heart rate (beats/min). In each group, the athletes were categorized into sympathicotonic and parasympathicotonic types based on the Kerdo index.

All girls attended rhythmic gymnastics classes three times a week, each lasting 90 min. The training sessions were designed in accordance with the requirements of the federal standard for this sport (Federal Standard of Sports Training for the Sport "Rhythmic Gymnastics," 2022). At the beginning of the experiment, the parents of all gymnasts provided voluntary written consent for their children to participate in the study, in compliance with the 2008 Helsinki Declaration on the participation of individuals in medical and biological

observations. The gymnasts in the EG followed the proposed methodology for developing coordination skills, tailored to the type of autonomic regulation of each child's body. The program was designed for 75 training sessions over 6 months. The coordination skills development methodology was implemented in EG for 18–20 min at the end of the preparatory part and at the beginning of the main part of each training session, in accordance with the traditional methodology outlined in the federal standard.

Preliminary testing of the coordination abilities of sympathicotonic gymnasts showed more pronounced results in dynamic coordination, while parasympathicotonic gymnasts exhibited stronger results in static coordination. The EG methodology was structured around sets of exercises grouped by developmental focus: body position awareness in space, differentiated response, static and dynamic balance, reaction speed, and the ability to repeat the rhythm. In the sympathicotonic gymnast group, the largest proportion of exercises (20%) focused on developing orientation ability, followed by exercises aimed at improving the ability to switch (15%). In the group of sympathicotonic gymnasts, coordination exercises were performed from general to specific, with progressively more complex tasks introduced that required strict adherence to spatial and temporal movement parameters. In the parasympathicotonic gymnast group, the largest proportion of exercises focused on improving differentiated ability (30%) and reactive ability (25%).

The exercises for parasympathicotonic gymnasts were performed from specific to general. A range of preparatory exercises was used, including individual acrobatic elements, exercises with weights, jumps, and obstacle courses. The sets typically consisted of 4–6 accessible exercises focused on improving a specific coordination ability. The number of repetitions for young gymnasts, depending on their autonomic regulation type, ranged from 4–6 to 8–10 times. Considering the preschool age of the children, the sets were predominantly performed using the game method. These sets were updated monthly and made progressively more challenging for the children. As the gymnasts progressed in mastering coordination skills, the standard repetition exercise method was replaced by a variable teaching method. In both groups, final testing of coordination skills and motor qualities was performed using specific tests. The coordination and physical fitness of the young gymnasts were assessed based on the test results, which included splits with the right and left legs (points), transverse split (points), standing bridge (points), lying bridge (points), 5 jumps on two legs over a skipping rope with forward rotation (points), and forward bend on a gymnastic bench (cm). The "walk on a gymnastic bench" test was used to assess dynamic balance (s), while static balance was determined using the "Romberg-2" test (s). General physical fitness was evaluated using the following tests: 10-m run (s), 6-min run (m), raising the body from a supine position in 30 s (number of repetitions), standing long jump with two legs (cm), and throwing a 1 kg stuffed ball with two hands from behind the head (cm).

Statistical processing of the obtained data was performed using the Statistica 10.0 software package. The arithmetic mean, standard error, and standard deviation (sigma) were calculated. The reliability of the differences in the indicator values was assessed using Student's t-test. A difference was considered statistically significant at $p < 0.05$.

Results

Analysis of the Kerdo index values in young gymnasts shows that 22 athletes (60.0%) have a sympathicotonic type of autonomic nervous regulation, characterized by a predominance of excitation processes over inhibition processes (+16 to +30 c.u.), c.u. - conventional units. In 18 athletes (40.0%), a parasympathicotonic type of autonomic nervous regulation was observed (–16 to –30 c.u.). None of the athletes exhibited values in the normal range (–10 to +10 c.u.).

The results of testing the coordination skills of gymnasts, taking into account the type of autonomic innervation of the cardiovascular system at the beginning and end of the study, are presented in Table 1.

Table 1. Boundary dynamics of static and dynamic coordination in girl gymnasts of different types of autonomic nervous regulation, $M \pm m$

No	Test	Experiment stage	CG, n = 19		EG, n = 21	
			Type of autonomic regulation		Type of vegetative regulation	
			ST	PT	ST	PT
Static coordination						
1.	Romberg test-2 (sec)	At the beginning	25.0±2.1	30.6±2.3#	23.2±2.7	33.1±2.5#
		At the end	28.4±2.2	34.2±2.6#	42.4±3.8*	52.3±4.3*#
2.	Standing bridge, points	At the beginning	1.6±0.3	2.3±0.4#	2.5±0.1	2.8±0.2#
		At the end	2.1±0.2	2.7±0.4#	3.3±0.3*	3.6±0.3*#
3.	Lying bridge, points	At the beginning	2.3±0.3	3.1±0.4#	2.4±0.4	3.3±0.5#
		At the end	2.8±0.4	3.7±0.5#	3.9±0.5*	4.9±0.5*#
4.	Forward bend on a gymnastic bench, cm	At the beginning	13.5±1.5	18.1±1.2#	13.7±1.2	19.2±1.6#
		At the end	16.6±1.9	20.2±1.1#	18.5±2.3*	23.2±2.4*#

Note. ST – Sympathicotonic; PT – Parasympathicotonic; * – There is a significant difference at the end of the study compared to the beginning of the experiment, $p < 0.05$; # – significant difference between athletes of different types of autonomic regulation, $p < 0.05$

At the beginning of the experiment, the values of all coordination skill indicators for the gymnasts in both the CG and EG did not differ significantly ($p > 0.05$), which confirms the correctness of the athlete selection for the study and supports the feasibility of performing further research.

After the completion of the pedagogical experiment, positive dynamics were observed in all coordination skill tests for athletes in both groups. Analysis of the testing results between the gymnasts in CG and EG shows that at the end of the experiment, an increase in the values of the indicators in all control exercises was recorded only for the athletes in EG ($p < 0.05$). In EG, the increase in the values of coordination skills in all tests was significantly greater compared to the athletes in CG (Figure 1).

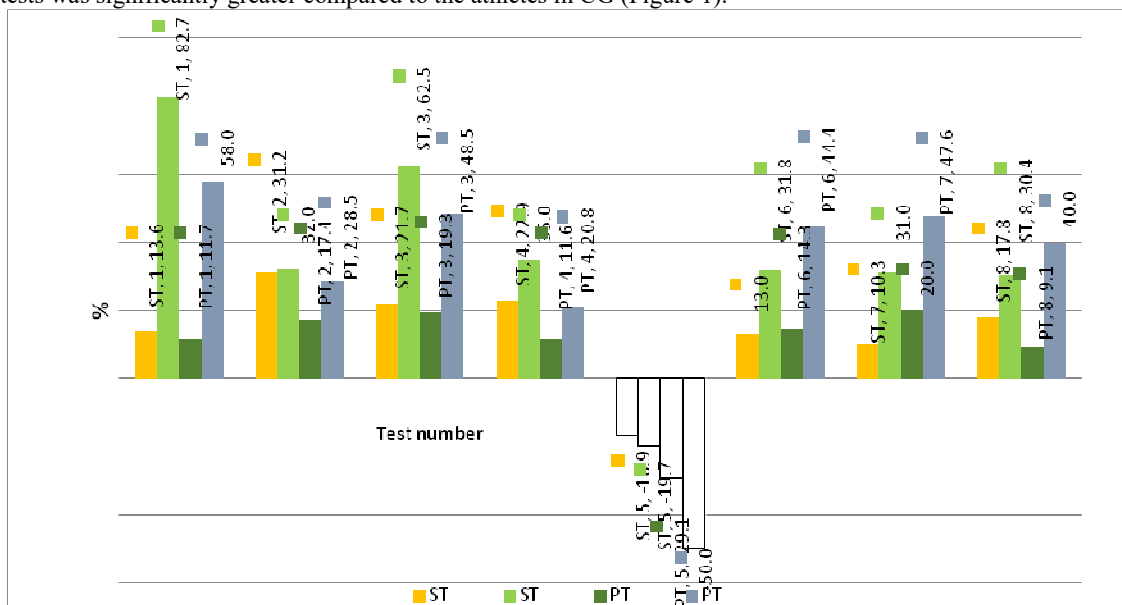


Fig 1. Increase in the values of the indicators of coordination tests in gymnasts in both groups at the end of the experiment

It was determined that the differentiated use of the proposed methodology for developing coordination skills in gymnasts in the EG, taking into account the type of autonomic regulation of the body, led to an increase in coordination skills compared to the CG of athletes, where the traditional training method outlined in the federal standard was used.

When testing the methodology for developing coordination skills in gymnasts in the EG with a sympathicotonic type of regulation, the greatest increase was observed in all static coordination tests (No. 1-No. 4). In test No. 1, the increase in the indicator was 82.7%; in test No. 3, it was 62.5%; and in tests No. 2 and No. 4, the increase was more than 30% compared to the beginning of the experiment. In the EG of gymnasts with a parasympathicotonic type of body regulation, there was a greater increase in the values of the indicators in dynamic coordination tests No. 5-No. 8. The highest increase was found in test No. 5 (50.0%). In all other dynamic coordination tests, the increase was 40.0% or more compared to the beginning of the experiment. These data indicate the effectiveness of the proposed methodology for developing coordination skills in young gymnasts when incorporating the features of the types of autonomic nervous regulation into their educational and training process. The development of human movement coordination leads to more effective development and improvement of other motor skills. To confirm this hypothesis, we analyzed the results of the boundary testing of motor skills, as shown in Table 2.

Table 2. Boundary values of motor test indicators in girls from both observation groups, $M \pm m$

No	Test	CG (n = 19)		EG (n = 21)	
		At the beginning of the experiment	At the end of the experiment	At the beginning of the experiment	At the end of the experiment
1.	10-m run, s	5.3±0.21	4.3±0.17*	5.4±0.34	3.5±0.48*
2.	Six-minute run, m	280.5±10.15	358.1±17.1*	294.0±10.16	509.8±40.11*
3.	Torso raises from a supine position for 30 s, number of repetitions	8.4±0.45	9.5±0.67	7.0±0.89	15.5±1.2*
4.	Standing long jump with two legs, cm	75.3±9.40	88.7±10.18	73.2±7.32	97.5±8.32*
5.	Two-handed throw of a 1 kg medicine ball from behind the head, cm	120.5±9.8	140.0±12.5	112.0±10.3	165.5±14.3*

Note: * There is a significant difference in the changes between the values at the beginning and end of the observation ($p < 0.05$).

At the beginning of the experiment, there was no significant difference in the development of the main motor skills between the young gymnasts in the CG and EG ($p > 0.05$). By the end of the study, an increase in the values of the indicators was observed in the motor tests for athletes in both groups.

However, the use of the proposed methodology for developing coordination skills in the EG gymnasts resulted in a significant increase in the values of indicators across all motor tests. In contrast, athletes in the CG showed a significant increase in the values of the indicators in only two control tests. At the end of the study, the magnitude of the increase in all tests was greater for EG gymnasts compared to CG athletes. These results suggest a positive transfer of motor qualities and skills, particularly in the development and improvement of coordination abilities.

Dicussion

An important condition for achieving high achievements in various sports is the good development of coordination skills in athletes (Razali et al., 2023; Donie et al., 2023; Mischenko et al., 2024; Vako et al., 2024). This motor skill is especially important in complex coordination sports, which include rhythmic gymnastics (Barreto et al., 2023). Therefore, the modification of various methods aimed at developing or improving coordination skills is a relevant area in the theory and methodology of sports (Hiley et al., 2019; Kokarev et al., 2023). It is known from scientific literary sources that the performance of motor loads is largely associated with the autonomic nervous regulation of the human body (Shoemaker, & Gros, 2024). In this regard, the use of knowledge about the features of the autonomic regulation of muscle activity is an important direction in the construction of training sessions to improve the effectiveness of athlete training and achieve high results (Liu et al., 2021).

The proposed methodology for constructing training sessions to develop coordination skills in gymnasts aged 6-7 years took into account that in athletes with a predominance of the sympathetic type of regulation, physical activity was aimed at developing orientation ability and the ability to switch attention. Coordination exercises were carried out from the general to the specific. In the group of gymnasts with a predominance of parasympathetic nervous regulation, a greater volume was occupied by sets of exercises that were aimed at improving differentiated and responsive ability. Their coordination exercises were built from the specific to the general. The use of these features of the autonomic regulation of the body in training sessions made it possible to significantly develop the coordination skill of gymnasts in the experimental group compared to the control group of athletes, where the generally accepted training methodology was used.

We agree with the opinion of M.Mangalam et al. (2024) that visual orientation, muscle-joint sense, vestibular and proprioceptive stability play an important role in gymnastics. At the same time, as a result of the experiment, we established the peculiarity of the formation of the coordination skill depending on the type of vegetative regulation. Thus, for most of the assessed indicators of coordination ability, gymnasts with the sympathicotonic type have a reliable advantage in motor coordination tests over the parasympathicotonic type of vegetative nervous regulation. The latter showed a predominance of results in static coordination tests. Perhaps, the identified specificity of the development of functional indicators and the development of such a motor skill as coordination is necessary in prospective observations. It can be a criterion for the selection of young athletes involved in rhythmic gymnastics. We believe that the revealed pattern indirectly indicates the peculiarities of the psycho-emotional status and characterizes athletes who are capable of performing well either in group performances or in individual directions of rhythmic gymnastics. Most successful and promising girls for this gymnastics have a sympathicotonic type (+16 to +30 c.u.) of autonomic nervous regulation, in whom excitation processes predominate over inhibition processes. Whereas for girls with a parasympathicotonic type (-16 to -30 c.u.) of autonomic nervous regulation, individual performances or soloing in a group of performing gymnasts can be recommended. It would be advisable to differentiate young athletes already at the initial stages of training, which will optimize the training process in this sport.

Our data on the general physical fitness of young gymnasts confirm the opinion of researchers that other motor qualities, such as strength, speed, flexibility and endurance, should be developed in parallel with the development of coordination skills (Rudd et al., 2017; Biino et al., 2023). Gymnasts with well-developed coordination abilities showed higher results in the main motor tests of general physical fitness. This combination in the development of special physical fitness ensures the achievement of high sports results in gymnastics.

Conclusions

A methodology for developing coordination skills in 6-7-year-old gymnasts at the initial stage of sports training is proposed, designed according to the type of vegetative regulation of their bodies. The study highlights the distinctive features in the development of coordination skills, with gymnasts having a sympathicotonic type of regulation showing superior results in dynamic coordination tests, while those with a parasympathicotonic status excel in static coordination tests. The development of a methodology for enhancing coordination, tailored to the identified features of vegetative regulation, led to a significant improvement in the coordination skills of gymnasts in the EG, compared to the CG, where the standard training methodology was used.

The advanced level of coordination skills in gymnasts from the EG facilitated more effective development of other motor qualities. This is reflected in the positive results of the test trials in this group, compared to the CG.

The proposed methodology for developing coordination skills can be effectively incorporated into training sessions for young gymnasts. The findings from this research can also inform the sports selection process for girls in rhythmic gymnastics.

Conflicts of interest. The authors declare no conflict of interest.

Acknowledgements. The authors would like to thank Falcon Scientific Editing (<https://falconediting.com>) for proofreading the English language in this paper.

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