International Journal of Evaluation and Research in Education (IJERE)
Vol. 14, No. 4, August 2025, pp. 2921~2930
ISSN: 2252-8822, DOI: 10.11591/ijere.v14i4.33185

Technology of adaptive physical education for children aged 7-9 years with autism spectrum disorder

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Article Info

Article history:

Received Oct 8, 2024
Revised May 23, 2025
Accepted Jun 2, 2025

Keywords:

Adaptation
Autism
Motor readiness
Physical development
Physical education

ABSTRACT

Analysis of the scientific and methodological literature indicates that the issue of scientific and methodological support for children with autism spectrum disorder (ASD) is insufficiently addressed, particularly for the age group of 7-9 years, which is the focus of this study. The aim of the research is to develop and empirically demonstrate a method for adaptive physical education for children with autism aged 7-9 years. The study involved 20 children attending a neurological rehabilitation center and a general education school. The methodology included the use of paired t-tests to compare indicators before and after the intervention. Key findings included significant improvements in physical indicators such as lung vital capacity (LVC), hand strength, and motor coordination. The practical significance of this research lies in the development of an effective adaptive physical education program that can be implemented in educational and rehabilitation institutions to support children with ASD. Future research prospects include increasing the sample size and conducting long-term observations to examine the sustainability of the obtained results.

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1. INTRODUCTION

The issue of adaptive physical education for children with autism spectrum disorder (ASD) has increasingly attracted the attention of researchers and specialists in recent decades; this is particularly significant given the rising statistics of ASD diagnoses in children [1], [2]. ASD is a group of neurodevelopmental disorders characterized by difficulties in social interaction and communication, as well as restricted and stereotyped patterns of behavior [3]. Children with autism exhibit varying degrees of symptom severity and require individualized approaches to education and development [4]. A critical area where children with autism face challenges is physical activity and movement [1]. Research has demonstrated that children with autism are less active than their neurotypical peers due to behavioral and motor characteristics, including difficulties with motor coordination, reduced muscle tone, and heightened sensory sensitivity [5], [6]. Limited physical activity increases the risk of comorbid conditions such as obesity, diabetes, and cardiovascular diseases [7]. In this context, adaptive physical education serves as an

essential tool that not only enhances the physical health of children with autism but also may contribute to social integration and the development of communication skills. However, despite the clear benefits, the implementation of adaptive physical education programs for this group of children faces several challenges. One of the main issues is the shortage of specialized skills and qualified professionals to work with children with autism [8]. This shortage is particularly acute in low-income countries, where educational and healthcare resources are limited [9].

According to international practices, successful adaptive physical education programs are based on an interdisciplinary approach involving educators, psychologists, physiotherapists, and other specialists [10]. These programs encompass a range of physical exercises tailored to the individual needs of children, aiming to develop motor skills, improve physical fitness, and enhance social skills [11]. However, these studies are often limited by small sample sizes or localized research, which complicates the generalization of results and the development of global recommendations. Therefore, the aim of this study is to provide more detailed and comprehensive data in the field of adaptive physical education for children with autism, which, in turn, will help improve the quality of life for children with autism and their families and facilitate their integration into society.

2. LITERATURE REVIEW

Research in the field of adaptive physical education for children with autism continues worldwide, revealing several significant trends. Studies focus on the development and implementation of programs aimed at enhancing the physical, psychological, and social well-being of children with autism [12]. International practice commonly employs a multidisciplinary approach, integrating physiotherapy, psychology, and special education to design comprehensive programs that address the individual needs of each child [13], [14]. One major trend is the investigation of the impact of physical exercise on the behavioral and emotional states of children with autism. Research has demonstrated that regular physical activity can help reduce anxiety, improve mood, and increase social interaction [15]–[17]. Data indicate that children with autism participating in adaptive physical education programs show better results in social interaction and communication skills compared to those not involved in such programs [18], [19]. It has been observed that optimal effectiveness is achieved through the use of structured programs that include both group and individual activities, highlighting the importance of a personalized approach [20]. Studies have shown that ASD encompasses poor motor coordination, low muscle tone, and difficulties in performing complex motor tasks [21], [22]. To address these issues, specialized exercises aimed at developing motor skills and improving overall physical fitness are recommended. This underscores the importance of creating a safe and supportive environment where children can develop their skills without fear of failure or judgment [23].

Despite the positive results of various studies, several limitations have been identified in the literature. One of these is the insufficient representativeness of the samples. Many studies have been conducted with small groups of autistic children, which complicates the generalization of results and limits their applicability. Additionally, there is a lack of research focusing on the long-term effects of adaptive physical education. Most current studies concentrate on short-term outcomes, such as improvements in physical indicators and behavior over a few months, which limits the ability to assess the full benefits of these programs. Therefore, there is a need for more extensive and long-term research. Another significant aspect is the shortage of qualified specialists capable of working with autistic children in physical education [24]. It has been observed that many trainers and instructors lack sufficient experience and knowledge to effectively adapt programs to the needs of children with autism, meaning that even well-designed programs may not yield the expected results due to staff inadequacies [25], [26]. This underscores the need for enhanced training and qualification of professionals working in this field.

In conclusion, despite significant progress in studying and developing adaptive physical education programs for children with ASD, this field remains an area for active research. Further investigation is required into effective methodologies, their adaptation to various age groups and cultures, and the development of training programs for specialists. Only a comprehensive approach that considers all these aspects will create effective and sustainable models of adaptive physical education, enhancing the quality of life for children with ASD and facilitating their integration into society.

The motivation for conducting this new study is driven by several key factors that underscore the need for a more in-depth investigation and development of effective methodologies in this field. Firstly, despite the increasing number of studies on adaptive physical education for children with ASD, there is a lack of comprehensive and long-term data that could provide a thorough understanding of the impact of physical exercise on the psychophysical development of children. Secondly, the diversity and heterogeneity of ASD symptoms necessitate an individualized approach, which complicates the development of universal physical education programs. The aim of the study is to develop and empirically substantiate a technology for adaptive physical education for children aged 7-9 years with ASD. Thus, the research objectives of the study:

i) To examine the characteristics of the physical development levels of children aged 7-9 years with ASD.
ii) To assess the extent of motor abilities in children aged 7-9 years with ASD.
iii) To develop a technology for enhancing adaptive physical education for children aged 7-9 years with ASD and empirically validate its effectiveness.

3. METHOD

3.1. Research design and participants

The study was conducted during the 2023-2024 academic year. The first phase (September-October 2023) involved an analysis of the scientific and methodological literature related to the research problem. The second phase (November 2023–April 2024) addressed the first and second research objectives. During the third phase (May 2024), a technology for enhancing adaptive physical education for children aged 7-9 years with ASD was developed (training program detailed in Table 1). This phase also involved analyzing the dynamics of physical development parameters and motor abilities. To determine the characteristics of physical development and motor abilities in children aged 7-9 years with ASD, these parameters were compared between children with ASD (10 individuals from the Neurocorrection Center "Erkemai") and those from a general education school no. 10 in Aktobe (10 individuals).

Table 1. Training program

No.	Program element	Description	Objective	Level of complexity
1	Ball lessons	Ball games: ball rolling, kicking with lower limbs, bouncing off the floor, catching with hands, tossing.	Development of visual-motor coordination and motor skills	Beginner-advanced
1.1	Rolling the ball towards and away	Rolling the ball towards and away: passing the ball between partners.	Development of visual-motor coordination	Beginner
1.2	Kicking the ball	Kicking the ball: targeted kicking with lower limbs.	Development of coordination and precision	Beginner-intermediate
1.3	Catching the ball	Catching the ball with both hands: tossing the ball.	Development of agility and hand motor skills	Beginner-intermediate
2	Development of lower limb muscle groups	Marching exercises: trampoline jumps, stationary walking, cycling/bike riding, jumping in place.	Development of muscle strength, coordination, and stability	Beginner-advanced
2.1	Marching	Marching in place and forward: marching with increased knee lift and arm movements.	Development of general motor skills and coordination	Beginner
2.2	Trampoline jumps	Trampoline jumps: repeated actions.	Reduction of sensory overload and decrease in anxiety	Intermediate
2.3	Jumping	Jumping in place: on two feet, progressing to one foot, moving forward, and backward.	Development of leg strength, coordination, and balance	Intermediate-advanced
3	Enhancement of balance skills	Balance exercises: walking on a line, standing on one foot, crawling through a tunnel.	Improvement of balance maintenance ability	Intermediate
3.1	Walking on a line	Walking on thin lines: on a bench, with obstacles.	Development of balance and concentration	Intermediate
3.2	Crawling through a tunnel	Crawling forward and backward: through tunnels made of boxes or chairs, hide-and-seek, moving objects.	Development of flexibility, agility, and imagination	Beginner
4	Improvement of climbing and crawling skills	Climbing: up a ladder, over a bench.	Development of motor skills and coordination	Intermediate
5	Symbolic play	Imaginative play: for example, "flying like an airplane," "jumping like a bunny."	Development of imagination and motor skills	Beginner-intermediate
6	Stepping or jumping	Progressive task complexity: entering a box, performing locomotion sequences, increasing box depth.	Development of coordination and movement planning	Intermediate-advanced

3.2. Measurements and data analysis

Body length (cm) was recorded using a stadiometer (RM-1 "Diakom"). Body weight (kg) was measured with electronic scales (VEM-150 "Massa–(A1)"). Chest circumference was assessed at maximum inspiration and complete expiration. Lung vital capacity (LVC) (ml) was determined using a portable dry spirometer (SSP). The degree of motor skill development in children aged 7-9 years with ASD was analyzed based on their level of motor readiness. This involved recording parameters of muscle power, speed, speed-strength qualities, and static endurance against fatigue. The muscle power of the hand was measured with a hand dynamometer (DRP-90). Static strength (SS) was assessed using a standing dynamometer (DS-200). Speed was evaluated by measuring the frequency of maximum steps during a 5-second stationary running test. Speed-strength qualities were determined by jump distance from a standing position and the distance of a 1 kg medicine ball throw. Static balance was assessed by the time of maintaining balance while standing on

the left foot. Data analysis in this study was conducted using IBM SPSS statistics software, version 28.0. To assess changes in physical indicators in children before and after the implementation of the adaptive physical education program, a paired t-test was employed. This test enabled the comparison of mean values of the studied parameters in two dependent groups (pre- and post-intervention) and determined whether these changes were statistically significant.

4. RESULTS AND DISCUSSION

Table 2 presents the results of the baseline levels of physical development and motor abilities in children aged 7-9 years with ASD. The data indicate that, in terms of body height, students with ASD exceed their general education counterparts by 0.5%, though this difference is not statistically significant ($p>0.05$). When comparing body weight, students with ASD are found to have an 18.8% higher weight than their peers from general education schools. The LVC of the examined students ranged from 830.1 to 1570.1 ml.

Table 2. Comparative parameters of physical development and motor abilities in children aged 7-9 years with ASD and students from a general education school

No	Parameters	Study population				Increase, %	Student's t-test	P
		General education school students, n=10		Students with ASD, n=10				
			S		S			
1	Body height (cm)	134.0	5.2	134.7	7.3	0.5	1.64	>0.05
2	Body weight (kg)	30.2	6.1	35.9	10.4	18.8	4.81	<0.05
3	LVC (ml)	1570.1	219.4	830.1	400.1	-89.1	15.61	<0.001
4	Chest circumference at inspiration (cm)	67.1	1.65	66.1	8.1	-1.5	1.81	>0.05
5	Chest circumference at expiration (cm)	63.4	1.8	62.1	9.4	-2.1	1.74	>0.05
6	Chest expansion (cm)	3.91	0.54	2.08	1.03	-87.9	12.8	<0.01
7	Strength of the right hand (SRH)	15.7	2.2	5.7	2.4	-175.1	16.4	<0.001
8	Strength of the left hand (SLH)	13.7	1.7	4.9	2.3	-179.1	17.8	<0.001
9	SS	43.3	4.5	17.4	5.7	-148.8	19.6	<0.001
10	Number of steps in place running for 5 seconds	17.7	2.1	13.2	3.1	-34.1	9.84	<0.01
11	Standing long jump (cm)	132.1	15.4	59.4	22.4	-122.3	18.91	<0.001
12	Throw distance of a 1 kg medicine ball (cm)	309.4	47.5	186.4	20.9	-65.9	17.62	<0.001
13	Static balance on the left foot (sec)	6.1	1.9	3.1	1.6	-96.7	15.4	<0.001

The absolute LVC for children with ASD was 830.1 ml, compared to 1570 ml for general education students, resulting in a relative decrease of -89.1%. The underlying factors for these parameters in children with ASD include difficulties in voluntary control of the breathing act, frequent breath holding, and irregular and unsteady breathing patterns. The differences in LVC are statistically not significant ($p>0.05$). Regarding hand strength, students with ASD lag behind general education students by 10 kg in right-hand strength and 8.8 kg in left-hand strength, corresponding to relative increases of 175.1% and -179.1%, respectively. For SS, children with ASD are behind their healthy peers by 25.9 kg, which represents a relative increase of 148.8%. Dominant factors contributing to this situation include difficulty in maintaining posture while seated, difficulty in holding a pen, and rapid hand fatigue during writing. The differences in hand and SS are statistically significant ($p<0.001$). Regarding the number of steps taken during a 5-second stationary running test, which reflects the speed of students with ASD, the absolute values for these students are 4.5 steps lower compared to their general education peers, resulting in a relative decrease of -34.1%. The differences are statistically significant ($p<0.001$). This is attributed to insufficient strength and mobility of neurological processes, as well as cognitive impairments in these children. In the standing long jump, children with ASD lag behind their peers from general education schools by 72.7 cm in absolute terms, which corresponds to a relative increase of 122.3%. The differences are statistically significant ($p<0.001$). The lower performance in this test is explained by several factors. From the outset, the test was challenging for children with ASD, who displayed instability in their stance. They generally made little effort to perform the jump, with no observable active leg thrusts, and lacked coordination in their arm and leg movements required for the task.

A similar situation was observed in the medicine ball throw test with a 1 kg weight. In absolute terms, students with ASD lagged behind their healthy peers by 123 cm, which corresponds to a relative decrease of -65.9%. The result for this test was relatively better compared to the standing long jump. The differences in both tests are statistically significant ($p<0.001$). In the static balance test on the left foot, students with ASD fell short of their general education peers by 3 seconds, corresponding to a relative decrease of -96.7%. The differences are statistically significant ($p<0.001$). These results are explained by the

difficulty children with ASD experience in maintaining balance on the left foot, which is related to spatial orientation challenges. Their underdeveloped daily living and work-related skills are attributed to difficulties in coordination. Based on the aforementioned results, we have developed a technology for enhancing adaptive physical education for children aged 7-9 years with ASD. Considering the identified deficiencies in physical development and motor skills, this technology incorporates elements of swimming and general developmental and health-oriented exercises.

For swimming sessions, we employed specialized equipment. We used associative-type boards that we prepared, including designs such as a fish with bubbles, a whale with a fountain, a dolphin, a frog, a turtle, and a rocket (standard swimming board size: 32×25 cm). As previously noted, children with these conditions often exhibit improper breathing. Additionally, these children showed reduced results in parameters such as "LVC," "chest circumference," and "chest excursion." Swimming equipment: the "frog" board was utilized to train the lower limbs in the breaststroke. The participant performed locomotion with the lower limbs in a manner similar to that of a frog.

Reduced results were also observed in the speed of these children. To address tasks aimed at improving speed, we used the "turtle" and "rocket" swimming boards. The "turtle" board was employed to promote a slow execution of tasks, while the "rocket" board was used for exercises requiring quick execution. During the period from November 2023 to March 2024, the swimming proficiency of children with ASD improved across several parameters: immersion with exhalation, gliding on the chest with lower limb movement, and gliding on the chest with proper breathing technique. Table 3 presents the dynamics of physical development and motor abilities for children aged 7-9 with ASD and those from a general education school post-intervention. The data indicate positive changes among ASD students. Although no significant changes were observed in height and body weight, substantial improvements were noted starting from the parameter of LVC. Notably, the relative increase in LVC improved from -89.1% to -56.3% when comparing children with ASD to their typically developing peers. This indicates a significant reduction in the gap between these groups, an achievement confirmed by a statistically significant difference ($p<0.001$). Measurements of chest circumference during inhalation and exhalation, as well as chest excursion, showed that the gaps in relative increases between children with ASD and their peers were notably reduced. The increase in these parameters reflects an enhancement in chest development and lung ventilation capabilities. Relative improvements in grip strength (both right and left hands) and SS also show positive trends. These results indicate substantial progress in the muscular development of children with ASD, though a noticeable gap with typically developing students remains. Nevertheless, the observed reduction in this gap is a promising sign and underscores the effectiveness of the applied methods. Improvements in the number of steps in place over 5 seconds, as well as speed-strength qualities such as standing long jump and ball throw, also demonstrate enhancements, reflecting progress in speed-strength qualities, and overall physical endurance.

Table 3. Dynamics of physical development and motor abilities of children aged 7-9 with ASDs and students from general education schools post-experiment

No	Parameters	Study participants				Increase (%)	Student's t-test	P
		General education school students, n=10		Students with ASD, n=10				
			S		S			
1	Body height (cm)	135.1	5.4	135.9	7.1	0.5	1.68	>0.05
2	Body weight (kg)	31.4	6.8	36.9	10.1	17.5	5.34	<0.05
3	LVC (ml)	1579.4	215.4	1010.2	430.1	-56.3	14.34	<0.001
4	Chest circumference on inhalation (cm)	67.3	1.71	67.0	8.0	-0.4	1.74	>0.05
5	Chest circumference on exhalation (cm)	63.9	1.7	63.4	8.9	-0.7	1.68	>0.05
6	Chest expansion (cm)	3.94	0.51	3.08	1.0	-27.9	11.64	<0.01
7	Right hand grip strength (RHGS)	15.8	2.3	9.1	2.1	-73.6	15.8	<0.001
8	Left hand grip strength (LHGS)	13.9	1.8	8.2	2.0	-69.5	14.3	<0.001
9	SS	43.9	4.6	23.4	4.9	-87.6	15.4	<0.001
10	Number of steps in place for 5 seconds	17.9	2.0	15.1	3.0	-18.5	8.81	<0.001
11	Standing long jump (cm)	133.1	14.9	78.2	23.1	-70.2	12.3	<0.001
12	Throwing a 1 kg medicine ball (cm)	310.4	46.5	201.4	21.9	54.1	13.8	<0.001
13	Static balance on the left leg (sec)	6.2	1.8	4.8	1.5	-29.1	12.8	<0.001

In static balance, the absolute value for children with ASDs increased from 3.1 to 4.8 seconds, while the relative difference between them and typical students decreased from -96.7% to -29.1%. Thus, the relative improvement in physical development and motor skills parameters for children aged 7-9 with ASDs can be attributed to the impact of the adaptive physical education technology we developed for these individuals. Studies on adapted physical education for children with autism have demonstrated significant

improvements in the participants' physical functioning. Numerous studies have confirmed the positive impact of physical activity on children with autism. For example, regular physical activity enhances overall physical fitness and motor coordination, reduces anxiety, and decreases stereotypic behaviors [16], [27]–[29]. The data showing substantial increases in LVC, improved hand strength, and overall coordination are consistent with findings from international research. Notably, this aligns with studies describing the beneficial effects of physical exercise on respiratory parameters and general physical endurance [30]. However, our research differs from many others in identifying more pronounced improvements in hand strength, which may be attributed to the nature of our program, which includes strength and coordination exercises such as standing jumps and ball activities.

The results of this study can be explained through several scientific theories and concepts that elucidate the impact of physical exercise on the development of children with autism. One of the primary theoretical foundations is neuroplasticity, which pertains to the brain's ability to change and adapt in response to various stimuli [31]. Physical activity promotes neuroplasticity, leading to the strengthening and development of neural connections, particularly in brain regions responsible for coordination, planning, and motor control [32]–[34]. The exercises included in the program appear to have stimulated these processes, thereby aiding in the improvement of motor skills and coordination among the children. The concept of sensory integration also plays a crucial role in interpreting the results. According to this theory, children often face challenges in processing and integrating sensory information during physical exercises, which may manifest as sensory overload or, conversely, as insufficient sensitivity [35], [36]. Exercises such as trampoline jumps or ball games can stimulate the sensory system and facilitate better integration of sensory signals, potentially reducing anxiety and stereotypical behaviors.

Motor control and learning theory posits that the enhancement of motor skills occurs through practice and repetition, allowing children with autism to develop automated motor patterns [37], [38]. The positive changes observed in coordination and strength support this theory, suggesting that regular, targeted physical activity can contribute to the development of more precise and coordinated movements. The primary limitation of this study is the small sample size, which may reduce the generalizability of the results. The limited number of participants might not be representative of the broader population of children with autism, thereby constraining the ability to identify general patterns. Another limitation is the absence of a control group. In this study, all children participated in the adapted physical education program, making it impossible to compare the results with those of children who did not undergo a similar program. Future research should include a control group to more clearly assess the effectiveness of the program and to account for the influence of other factors on the outcomes. Additionally, the study did not account for potential differences in the baseline health of the children or other individual characteristics, such as cognitive development levels or the presence of comorbid conditions. Future studies could stratify participants more thoroughly based on various criteria to consider the impact of these factors and enhance the precision of the analysis.

Overall, the study results confirm the significant positive impact of adaptive physical education on the physical and psycho-emotional well-being of children with ASD. It has been established that regular physical exercise contributes to improvements in physical indicators such as vital capacity (VC), hand strength, and coordination. Additionally, positive effects on social skills and a reduction in anxiety have been observed. The findings align with several international studies, confirming the universal benefits of physical exercise. However, variations in emphasis and methodologies suggest the need for individualized approaches and program adaptations based on the specific needs and characteristics of the children. It is crucial to continue exploring various aspects of physical education to effectively support the development of children with ASD.

5. CONCLUSION

The study demonstrated that the adaptive physical education program positively affects the physical condition of children aged 7-9 years with ASD. Key findings included significant improvements in physical parameters such as lung volume, hand strength, and movement coordination. These results support the theories of neuroplasticity, sensory integration, and motor control, illustrating that targeted physical activity can enhance the physical, psychological, and emotional health of children with autism.

The practical value of this research lies in the development and testing of adapted physical education programs that professionals can utilize for the treatment of children with ASDs. Educators, trainers, and specialists working with children with special needs can use the findings to design effective physical education programs. In schools and specialized centers, the developed exercises can be integrated into the curriculum and applied in daily practice, which will help not only improve the physical fitness of children but also their social adaptation and integration into society.

It is important to investigate the impact of this program on children with different types of ASD and from various demographic groups. Long-term studies are also recommended to examine the sustainability of positive effects and potential changes in the physical and mental health of children over time. Future research may also focus on adapting programs for different age groups and developing specialized exercises tailored to the individual characteristics of children with autism, leading to more effective and personalized programs that meet the needs of various groups of children with special needs. Including an interdisciplinary approach, such as collaboration among teachers, psychologists, and physiotherapists, may also contribute to the development of comprehensive support and rehabilitation plans for children with autism.

FUNDING INFORMATION

The research received no funding.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
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R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICTS OF INTEREST STATEMENT

The research has no conflict of interest.

INFORMED CONSENT

All parents or legal guardians of the participants gave their written informed consent before the commencement of the research.

ETHICAL APPROVAL

The authors declare that the work is written with due consideration of ethical standards. The study was conducted in accordance with the ethical principles approved by the Ethics Committee of Aktobe Regional University named after K. Zhubanov (Protocol No 730HWS of October 2023).

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article [and/or its supplementary materials].

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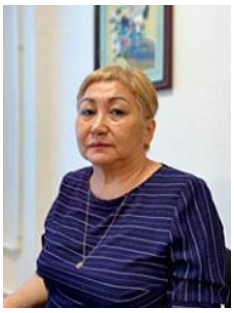

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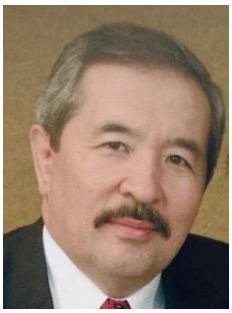

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