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EFFECTIVENESS OF VIRTUAL REALITY TECHNOLOGY IN IMPROVING THE PHYSICAL FITNESS OF UNIVERSITY STUDENTS

EFECTIVIDAD DE LA TECNOLOGÍA DE REALIDAD VIRTUAL PARA MEJORAR LA CONDICIÓN FÍSICA DE ESTUDIANTES UNIVERSITARIOS

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ABSTRACT

The modern information environment is characterized by the introduction of the latest technologies into the sports training system across various sports. One such innovation is the development of virtual reality (VR) technology, which is widely used in different spheres of life and increasingly accompanies people in their daily activities. Sports serve as an innovative platform where modern technologies are integrated into training processes and the management of athletes' physical conditions. The use of VR in the training process is gaining greater significance today. The aim of this article is to analyze the effectiveness of VR technology in fitness aerobics classes as part of the educational and training process in a higher education institution. The article provides an overview of the potential applications of VR technology in sports and sports training. The inclusion of VR systems in fitness aerobics classes was tested in the study. The results of the pedagogical experiment confirmed the research hypothesis that the use of VR technology in fitness aerobics classes leads to a significant improvement in participants' physical fitness. It was concluded that VR technologies offer an alternative approach to fitness training, opening up new opportunities for enhancing the effectiveness and engagement of workouts. The use of VR technology in fitness aerobics contributes to health preservation and fosters a positive attitude towards physical education among student youth.

Keywords:

Virtual Reality, VR Technology, Students, Fitness, Training Process.

RESUMEN

El entorno informativo actual se caracteriza por la introducción de las últimas tecnologías en el sistema de entrenamiento deportivo en diversas disciplinas. Una de estas innovaciones es el desarrollo de la realidad virtual (RV), ampliamente utilizada en diferentes ámbitos de la vida y que acompaña cada vez más a las personas en sus actividades diarias. El deporte sirve como plataforma innovadora donde las tecnologías modernas se integran en los procesos de entrenamiento y en la gestión de la condición física de los atletas. El uso de la RV en el proceso de entrenamiento está adquiriendo mayor relevancia en la actualidad. El objetivo de este artículo es analizar la efectividad de la tecnología de RV en clases de aeróbic como parte del proceso educativo y de formación en una institución de educación superior. El artículo ofrece una visión general de las posibles aplicaciones de la tecnología de RV en el deporte y el entrenamiento deportivo. En el estudio se puso a prueba la inclusión de sistemas de RV en clases de aeróbic. Los resultados del experimento pedagógico confirmaron la hipótesis de investigación de que el uso de la tecnología de RV en clases de aeróbic conlleva una mejora significativa en la condición física de los participantes. Se concluyó que las tecnologías de RV ofrecen un enfoque alternativo para el entrenamiento físico, abriendo nuevas oportunidades para mejorar la efectividad y la participación en los entrenamientos. El uso de la tecnología de realidad virtual en la gimnasia aeróbica contribuye a la preservación de la salud y fomenta una actitud positiva hacia la educación física entre los jóvenes estudiantes.

Palabras clave:

Realidad Virtual, Tecnología de RV, Estudiantes, Fitness, Proceso de entrenamiento.

INTRODUCTION

Today, virtual reality (VR), created through advances in information technologies, is a complex system of mathematical operations and computer algorithms that combines immersive software, advanced hardware and computer-generated graphics to create realistic three-dimensional environments (Zaitseva, 2021). Beyond its technical foundations, VR has evolved into an educational resource that facilitates experiential learning by enabling users to interact with simulated environments that closely replicate real-world situations. The systematization of experiences in virtual reality laboratories has shown that these environments promote active participation, improve practical skill acquisition and create opportunities for innovative teaching and learning processes across different educational contexts (Medina-Salmerón, 2025).

In a broader context, VR is an artificial, constructed environment that simulates real conditions based on specifically formulated requirements and controlled scenarios. VR provides new opportunities but also imposes certain limitations related to the technical characteristics of the equipment and to users' preparedness to interact effectively with immersive technologies. As one of the most representative disruptive technologies in contemporary education, virtual reality supports the transformation of learning by promoting interactive, personalized and experiential educational experiences that increase student engagement and facilitate the development of practical competencies (Baute-Rosales et al., 2026).

Initially introduced in the entertainment industry, VR systems are now increasingly used by researchers in diverse fields of human activity (Deng et al., 2025). The global experience of creating virtual environments and conducting scientific experiments demonstrates the growing relevance of VR technologies in physical education and sports (Vignais et al., 2015), where they facilitate the acquisition of new motor experiences while reducing technical errors during physical performance. Furthermore, evidence from educational innovation projects indicates that immersive virtual environments strengthen experiential learning by allowing learners to safely practice complex tasks and receive immediate feedback in controlled settings (Medina-Salmerón, 2025).

However, despite its advantages, the initial pace of VR integration into physical education and sports was relatively slow. For many years, the sports industry focused primarily on developing simple and accessible products for the general public. Over time, sports schools, federations and clubs gradually recognized the educational and training potential of immersive technologies (Akhmetshin et al., 2025). Recent studies also emphasize that the integration of disruptive digital technologies, including virtual reality, contributes to the transformation of educational and training models by fostering innovation, increasing learner motivation and supporting competency-based learning environments (Baute-Rosales et al., 2026). Scientific research therefore identifies VR as one of the most promising tools for improving athletes' physical, technical, tactical, psychological and cognitive preparation.

In the field of physical education and sports, VR technologies allow for the creation of an artificial, fully controlled environment that simulates real sports conditions. By simultaneously using motion capture and feedback systems (visual, auditory), it is possible to achieve full immersion of the participant in the created virtual scenario, enabling interactivity and real-time correction of the athlete's actions in the virtual setting.

The creation of realistic images relies on tracking the athlete's movements in both space and time. This is achieved using special motion sensors. These sensors gather data, which is then processed by a computer. The information is subsequently visualized through virtual software algorithms. In this sense, computer programs serve as a benchmark for mastering the technique of performing the necessary physical exercises perfectly (Ruffaldi et al., 2011). This technology is already being used in nearly all sports. Currently, such programs are effectively applied in sports such as artistic and rhythmic gymnastics, athletics, ski acrobatics, diving, swimming, skiing, rowing, martial arts, bobsledding, boxing, trampoline jumping, and many others (Vignais et al., 2015).

VR technology also facilitates a detailed analysis of the technique involved in performing sports exercises, identifying even the slightest deviations and errors in execution. For instance, a volleyball player aiming to improve their "blocking" technique, or a sprinter in track and field striving to increase their speed on a treadmill to enhance their previous performance, can analyze their movements through a computer-generated image and compare them with the standard parameters calculated by specialized software (Faure et al., 2020). Three-dimensional models can accurately measure the speed and trajectory of movements that require correction (Ruffaldi & Filippeschi, 2013). Consequently, the "trial and error" method is becoming obsolete, as it is increasingly viewed as outdated and inefficient. The importance of the latest VR-based technologies for advancing physical education and sports systems is difficult to overestimate.

The implementation of cutting-edge technologies enables the development and deployment of comprehensive computer programs that are detailed algorithms for modeling the techniques of specific motor tasks. These programs offer solutions to the pressing challenges in physical education and sports training. VR programs, by creating a "presence effect," aim to foster a clear understanding of the optimal execution of individual elements of exercise technique, as well as a holistic perception of physical exercises as distinct motor tasks (Staurset & Prasolova-Førland, 2016). Additionally, VR software enhances engagement in various physical activities and sports, motivating users to consistently work on their physical improvement.

However, researchers have noted that several challenges must be addressed for VR to be fully integrated into physical education and sports practices. Primarily, these challenges relate to the complexity and sometimes unstable performance of technical devices, which can be affected by issues such as computer viruses, freezing, or unexpected failure (Miller et al., 2017). There are also difficulties related to the development of user skills in managing these advanced programs, as users are not immune to errors. Moreover, mastering complex VR technologies takes time (Liu et al., 2020). The criterion for successful training in using VR technology is often described as the sensation of complete integration between the objective and virtual realities.

Certain limitations in the use of VR technology are imposed by the VR accessories that enable users to view an artificially created virtual space. These accessories provide full sensory experiences, which positively contributes to the increasing popularity of VR technology (Bailenson et al., 2008). It is widely believed that VR, when combined with mobile gadgets, offers an economical and accessible solution. Accessories optimized for smartphones are designed simply, consisting of two lenses and a case with additional reinforcement. However, this is not the only available prototype. Typically, VR glasses consist of a plastic case, a screen with a partition, aspherical lenses that focus the image, and a wireless transmitter.

These glasses create a sense of presence by transmitting an adaptive image to each eye separately, while tracking all head movements through a gyroscope and accelerometer. To initiate the "virtualization of material," a specialized application and calibration are required. The specific VR product used depends on the operating system (OS) in use, and of course, VR cannot function without the appropriate software (Bideau et al., 2010).

However, despite the significant advantages, VR glasses also have their drawbacks. For instance, they do not allow users to move freely or accurately perceive and interact with real events happening at that moment. Moreover, prolonged use of VR glasses can lead to a form of dependency. Athletes may need time to readjust to working without the glasses after using them extensively (Craig, 2013). Experts argue that a common mistake in virtual simulation is the attempt to replicate reality too closely, while objective reality will always have unique distinctions. As a result, users may develop the illusion that they can defy the laws of physics or alter real-world events (Kim, Ko, 2019).

Another challenge faced by VR users is the lack of adequate preliminary training for its proper use. Athletes who have not undergone such training will consistently demonstrate subpar results, even if they are equipped with the most advanced 3D systems (Tirp et al., 2015).

Currently, several strategies exist to mitigate the disadvantages of VR technology. Foremost among these is fostering a positive attitude among coaches and athletes toward this technology, providing them with proper theoretical training, and enhancing the methodology for using VR in training (Craig et al., 2009). Also, the practice of using VR devices shows that their technical characteristics are gradually improving. These devices are becoming lighter and more efficient, which leads to better performance outcomes in sports. Presently, technological innovations in visualization, motion tracking, and computing capabilities are aimed at addressing the challenge of developing simulated virtual realities optimized for training sensorimotor skills in various sports.

The practice of using VR technology in sports training demonstrates that it is capable of performing the following tasks (Jackson, 2021; Nor et al., 2020):

- Enhancing the conditions of the educational and training process, providing athletes with a better understanding of their academic performance and physical development, and making their personal achievements more impactful.

- Offering the opportunity to select more suitable organizational methods, training tools, and techniques that can help reveal athletes' individual preferences, unique abilities, and personal talents.
- Increasing athletes' interest in the training process, fostering a search for innovative methods, and encouraging them to enjoy the journey of personal sports improvement.
- Providing optimal conditions for improving athletes' physical fitness, promoting better health outcomes, and enhancing motivation to pursue their chosen sport.
- Allowing for more effective control and evaluation of athletes' progress and final results at all stages of their preparation.

Based on the above, the purpose of this study was to analyze the effectiveness of using VR technology in fitness aerobics classes as part of the educational and training process in higher education institutions.

The research hypothesis was that the use of VR technology in fitness aerobics classes would lead to a significant improvement in the physical fitness of participants.

MATERIALS AND METHODS

To achieve the stated goal, several methods were used in the study. Among them were the analysis of psychological, pedagogical, scientific, and methodological literature, as well as the use of a pedagogical experiment.

The pedagogical experiment was conducted during the second semester of the 2021-2022 academic year within the fitness aerobics section at Kazan Federal University. The study involved 32 female students in their 1st and 2nd years of study, who were divided into two groups. The first group, the experimental group (EG, n = 16), consisted of individuals who trained in fitness aerobics classes twice a week using the Icaros system. This system includes VR glasses and a specialized simulator designed to simulate flight. Participants lie on the simulator face down, gripping the handles with their hands, and control the simulator in a virtual race displayed in the VR glasses.

The Icaros system allows for training various muscle groups, particularly the upper limbs and abdominal muscles, and is highly effective in developing coordination, balance, strength, and motor response. This system was preliminarily tested at the Research Laboratory of Augmented/Virtual Reality and Game Development.

The control group (CG, n = 16) participated in fitness aerobics classes following the traditional program.

Physical fitness was assessed through pedagogical testing, which measured the level of key physical qualities: speed (30 m run, seconds); agility (shuttle run 4x9 m, seconds); speed-strength (standing long jump); strength (push-ups, repetitions; sit-ups in one minute, repetitions); and flexibility (forward bend from a sitting position, cm).

The experiment was conducted in several stages (Table 1).

Table 1. Stages of the pedagogical experiment.

Stage	Content of the stage
Preparatory	Defining the relevance, goals, objectives, object, and subject of the experiment
Organizational	Preparing the equipment for experimental testing, selecting participants
Practical	Using the Icaros system during the training of the female students in the experimental group
Summarizing	Evaluating the results (determining the dynamics of physical fitness indicators)

The subsequent processing of the pedagogical experiment results was carried out using methods of mathematical statistics. The objective was to identify differences in the distribution of physical fitness indicators when comparing two independent empirical distributions. For this purpose, the Student's t-test for independent samples was used.

To calculate the empirical value of the t statistic, the following formula was applied (F1)

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \qquad \text{(F1)}$$

where

$\bar{X}_1$ and $\bar{X}_2$ are the sample means of the experimental and control groups,

s_1^2 and s_2^2 are the sample variances,

n_1 and n_2 are the sample sizes.

Sample means and variances were calculated using the standard formula 2 and 3:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$
.... (F2)

$$5^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$$
.... (F3)

The degrees of freedom for the t distribution were determined (F4) as:

$$df = n_1 + n_2 - 2$$
.... (F4)

In addition to hypothesis testing, the magnitude of differences between the two groups was quantified using Cohen's effect size coefficient. The effect size was computed according to the formula 5:

$$d = \frac{\bar{x}_1 - \bar{x}_2}{s_{pooled}}$$
.... (F5)

where the pooled standard deviation is defined (F6) as:

$$s_{pooled} = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}}$$
.... (F6)

This indicator made it possible to evaluate not only statistical significance but also the practical relevance of the observed differences in physical fitness indicators.

RESULTS AND DISCUSSION

The obtained research data are presented in Tables 2 and 3.

Table 2: Physical fitness indicators of female students engaged in fitness aerobics before the pedagogical experiment (X±m).

Indicators	CG (n=16)	EG (n=16)	Significance level	
			t	P
30 m run, sec	5.62±0.11	5.57±0.15	2.12	>0.05
Shuttle run 4x9 m, sec	10.87±0.07	10.80±0.09	1.87	>0.05
Standing long jump, cm	175.32±1.28	176.44±1.33	2.03	>0.05
Push-ups (flexion and extension of arms), reps	15.64±1.16	16.18±1.24	2.06	>0.05
Sit-ups in 1 min., reps	41.25±2.26	40.20±2.42	1.97	>0.05
Forward bend from sitting position, cm	13.94±1.29	13.34±1.22	1.72	>0.05

Note: t critical = 2.120 (p=0.05); t critical = 2.921 (p=0.01)

According to the data presented in Table 2, by the beginning of the formative experiment, the students in both groups exhibited nearly identical indicators, with no statistically significant differences (p>0.05). The level of development of speed (30 m running time was 5.61±0.12 seconds and 5.57±0.14 seconds, respectively), agility (4x9 m shuttle run time was 10.86±0.06 seconds and 10.80±0.08 seconds, respectively), speed-strength (standing long jump results were 175.31±1.29 cm and 176.44±1.34 cm, respectively), strength (flexion and extension of arms in a prone position were 15.63±1.17 times and 16.18±1.23 times, respectively), and sit-ups in 1 minute (41.24±2.27 times and 40.20±2.41 times, respectively) were similar. Flexibility (forward bend from a sitting position results were 13.95±1.23 cm and 13.34±1.15 cm, respectively) also showed no significant differences.

Table 3: Physical fitness indicators of female students engaged in fitness aerobics after the pedagogical experiment (X ± m).

Indicators	CG (n=16)	EG (n=16)	Significance level	
			t	P
30 m run, sec	5.57±0.08	5.27±0.12	2.54	<0.05
Shuttle run 4x9 m, sec	10.81±0.06	10.12±0.05	2.71	<0.05
Standing long jump, cm	176.29±1.21	184±1.27	2.88	<0.05
Push-ups (flexion and extension of arms), reps	16.27±1.02	21.10± 1.14	3.41	<0.01
Sit-ups in 1 min., reps	41.98±2.08	48.15±2.34	4.55	<0.01
Forward bend from sitting position, cm	14.01±1.16	18.54±2.22	5.83	<0.01

Note: t critical = 2.120 (p=0.05); t critical = 2.921 (p=0.01)

Overall, the data obtained from the study indicate that the physical fitness indicators of both groups of female students improved by the end of the academic year (Table 3). However, the control group showed only minor changes, while the students engaged in fitness aerobics using virtual reality technologies demonstrated significant improvements across all physical fitness indicators.

For example, the 30-meter run, which tests acceleration ability, showed that the students in the experimental group (EG) performed better by 0.3 seconds ($p < 0.05$) compared to the control group (CG).

The next test, the 4x9 meter shuttle run, assesses agility. The results show that the experimental group outperformed the control group by 0.69 seconds ($p < 0.05$).

The standing long jump, a key test for female students involved in fitness aerobics due to the frequent use of jumping exercises in this sport, also revealed a significant improvement. The students in the experimental group achieved better results than those in the control group, with a difference of 7.76 cm ($p < 0.05$).

The following two tests assess the development of strength in the abdominal muscles (sit-ups in 1 minute) and arms (push-ups, flexion and extension of the arms in a prone position). In the sit-up test, the experimental group (EG) students performed 6.17 more repetitions than the control group (CG) students ($p < 0.05$). The results of the arm strength test (push-ups) also showed a significantly better outcome for the EG students compared to the CG, with a difference of 4.83 repetitions ($p < 0.01$).

The flexibility test (forward bend from a sitting position) demonstrated that the EG students outperformed the CG students by 4.53 cm ($p < 0.01$), indicating a significant improvement in hip joint mobility.

Furthermore, based on the survey results, there was an observable increase in the students' motivation to participate in fitness aerobics, along with positive changes in their overall physical condition.

The minor improvements in the physical fitness of the control group students suggest low efficiency, likely due to a lack of conscious motivation for fitness classes, low interest levels, and poor performance of the proposed exercises. In contrast, the students in the experimental group, who participated in fitness aerobics using VR technologies, showed significant improvements in their results.

Given that the experimental group's training incorporated VR technologies, it can be argued that this contributed to the achievement of higher outcomes. Therefore, the findings provide experimental confirmation of the proposed hypothesis. This suggests that the use of VR technologies in fitness aerobics is an effective method for developing the physical qualities of students. These improvements include enhanced physical condition, better cardiovascular system activity, increased ability to cope with stress, and a reduction in body weight.

The study also demonstrated that the use of VR stimulates emotions and consciousness, which enhances the educational and training process. The information is presented in a novel, unconventional format that challenges the preconceived notions and stereotypes typically held by students involved in fitness aerobics.

Special studies have noted that the use of VR technology by athletes activates the cerebral cortex and affects its emotional component, allowing athletes to reach a new level of performance in the complex process of sports training (Bailenson et al., 2008). However, to fully harness the advantages of this technology, meticulous and systematic training is recommended. To adapt more quickly to the novel sensations brought about by VR, training in small groups under the guidance of experienced specialists is advised, followed by an analysis of the results from completing the relevant tasks. Practical experience shows that active participation in simulated virtual games can be beneficial for rapid adaptation (Miles et al., 2012).

We agree with other researchers (Tirp et al., 2015) that when implementing the educational and training process in VR, it is essential to monitor the functional state of the body while considering the individual and age-related characteristics of athletes. Physical exercises should be selected on a differential basis, using the principles of gradual progression, consistency, and accessibility. The process of mastering motor skills and abilities in athletes also depends on their awareness, engagement, and the professional skills of the instructor. This process is significantly enhanced by the use of VR technology.

Of particular importance when conducting training sessions is the issue of dosing physical activity, taking into account the athletes' health and physical development. An innovative approach to organizing physical education classes, supplemented by modern and unconventional methods, can aid in addressing this issue. These methods include computer testing in VR, the use of digital materials, innovative training and diagnostic equipment combined with virtual reality modules, and automated control systems for managing the educational and training process (Staurset & Prasolova-Førland, 2016). However, as with any innovation, VR technologies in fitness training have both advantages and disadvantages.

Benefits of using VR in fitness:

- **Increased motivation:** VR can create an engaging environment that encourages individuals to exercise more intensely and helps maintain their motivation.
- **Expanded training options:** VR offers a variety of exercises and workouts, including simulations of different sports and the use of specialized exercise equipment.
- **Improved interaction with the environment:** VR can provide an ideal training environment, free from real-world limitations such as weather conditions or lack of access to specialized facilities.
- **Increased safety:** Training in a controlled VR environment reduces the risk of injury and accidents.

Disadvantages of using VR in fitness:

- **High costs:** Implementing VR requires a significant investment in hardware, software, and ongoing technical support.
- **Technical issues:** VR usage can be accompanied by technical problems such as image lag or hardware compatibility issues.
- **Limited interpersonal interaction:** VR may reduce opportunities for face-to-face interaction with coaches and other athletes, which could be important to some individuals.
- **Potential health concerns:** Some people may experience discomfort, increased fatigue, or worsening of symptoms when using VR, as it may affect their sense of orientation and strain the visual system.

CONCLUSION

Summarizing the results of the study, it should be noted that the concept of "virtual reality" is increasingly being applied across all areas of society. Physical education and sports, in particular, are no exception when it comes to adopting the advanced achievements of science and technology. New technologies have rapidly entered both professional sports and general physical culture, including fitness. The introduction of new IT technologies has significantly enhanced the effectiveness of the training process. They have provided tangible benefits to athletes, coaches, and teachers by optimizing the process of sports and physical training, making training safer. The use of modern VR technologies has greatly increased motivation and interest in physical activity. It offers a unique opportunity to create an immersive environment in which individuals can interact with the virtual world and perform a variety of physical exercises and workouts.

Currently, these technologies are advancing to a new level, and modern fitness trainers are increasingly incorporating them into their practice. However, virtual reality is not without its drawbacks. Some challenges include certain inconveniences when performing motor tasks in specialized equipment, as well as the still considerable cost of the devices. Nevertheless, despite the temporary shortcomings of virtual and augmented reality, VR technology holds strong prospects for further development.

The results of our study demonstrated that VR technologies offer an alternative approach to fitness training, opening up new opportunities to enhance both the effectiveness and engagement of training. Additionally, our study revealed that fitness aerobics sessions using VR technologies lead to significant improvements across all physical fitness indicators for female students. The use of VR technologies in fitness aerobics not only supports health but also fosters a positive attitude towards physical education among student youth.

The limitations of the study include the sample size and the age composition of participants in the pedagogical experiment. The potential for future research could involve analyzing the prospects for using VR technologies in other sports.

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CONFLICT OF INTEREST:

The authors declare no conflict of interest.