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Using Virtual Reality Sports Simulators in Adaptive Physical Education of Female College Students with Functional Disabilities

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Abstract

To evaluate the effectiveness of an adaptive physical education (APE) program using VR technologies, we studied the physical development and vitality indicators of college female students in two groups: those with and without functional health limitations (N = 70 each). Students with disabilities were randomly divided into experimental and control groups of 35 people each. The experimental group participated in physical education classes using VR. The health assessment included heart rate, blood pressure, and subjective health assessments. Physical development was assessed by the biological age index (BAI) by Voitenko, static balance duration, and breath-holding time. Psychological activity was assessed using the Mindfulness Attention Awareness Scale (MAAS), the Rezapkina Vitality Test, and the Subjective Vitality Scale (SVS). The delayed effect was assessed using a questionnaire. Students with functional impairments initially demonstrated a significant decrease in overall vitality, physical activity duration, and more negative health self-perception. After the virtual reality sessions, they showed a restoration of physical development and vitality indicators to levels close to healthy, as well as a decrease in BAI. The delayed effect was confirmed after three months. The use of virtual reality technologies in the APE program effectively improves the physical development and activity (vitality) of students with functional health impairments.

Keywords: virtual sports; adaptive physical education; functional health disorders; college students; activity; physical development; health; vitality; virtual reality technologies

1. Introduction

The importance of this study comes from the global rise in the number of individuals, including young people, experiencing various health issues (Kuriakose & Amaresha, 2024; Song et al., 2021). As a result, more students with health-related problems are enrolling in colleges and universities (Gavurova et al., 2022). For example, in the United States, the number of students with disabilities reached 7.5 million in the 2022–2023 academic year, a 3% increase from 2019–2020 (Houtenville & Bach, 2025). Among Czech students, the prevalence of somatic complaints, anxiety, and depression was 72.2%, 40.3%, and 52%, respectively; among Slovak students, these figures were 69.5%, 34.6%, and 47% (Gavurova et al., 2022). In Russia, at least 60% of school and university students had health disorders in 2018, with only 14% of senior students classified as practically healthy (Markova & Ryutin, 2020). Globally, students with disabilities constitute more than 20%

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of the college population. Most of these conditions involve functional rather than organic health issues. Functional illnesses are conditions where medical exams do not reveal clear organic pathology, yet functional disturbances and distressing symptoms are present (Reuber et al., 2005), and such conditions are seen across nearly all medical specialties (Wessely et al., 1999).

Functional health disorders, like organic ones, often occur alongside reduced physical activity and can affect physical development. A longitudinal study in the United States found that 11.6% of adults have limitations ranging from impaired vision to restricted mobility, and those with disabilities show lower vitality and decreased aerobic activity (Carroll et al., 2014). Students with health limitations tend to lead more sedentary lives and are more likely to be overweight (Cook et al., 2015). In Spain, similar patterns of decreased daily activity have been observed among students with functional health disorders (Pans et al., 2021). Russian studies have reported notable differences in physical development between students with health limitations and those with normal health. These differences may result from initially lower anthropometric measures linked to underlying health issues and a slower rate of biological growth during adolescence (Misharina et al., 2008). Additional findings from Russia indicate that 94% of first-year students exempt from physical education had a biological age about 50% higher than their chronological age. These students also reported more health complaints, pain, and depressive symptoms (Razmakhova et al., 2019).

Reduced physical activity can worsen health problems and affect age-related physiological traits. A large-scale study in Colombia involving more than 2000 students found that lower physical activity levels were associated with a higher risk of metabolic health issues (Pérez-Muñoz et al., 2024). Physical development was measured through somatic and anthropometric assessments, while physical activity was evaluated using standardized questionnaires. The authors concluded that physical activity, biological maturation, and overall health are closely connected (Pérez-Muñoz et al., 2024). In China, research found links between physical activity and developmental indicators, such as height and body mass, among university students enrolled in adaptive physical training courses (Yang et al., 2024).

Students with health limitations often avoid physical activity and physical education classes, even when their limitations are functional rather than severe. In the United States and many other countries, these students are frequently excused from standard physical education and placed into specialized groups (Bertills & Björk, 2024; Herbison et al., 2023; Benzinger et al., 2022; Leahy et al., 2021). However, the effectiveness of traditional physical education programs for students in these medical groups is limited because the students often have negative attitudes toward physical activity and tend to avoid participation (Proshljakov et al., 2001). Avoiding involvement in physical programs decreases already low levels of physical activity, leading to secondary health problems, poorer physical development, and higher risks of obesity, hypertension, anxiety, and depression (Fitzgerald et al., 2022).

This challenge has prompted many countries to develop adaptive physical education (APE) programs to reduce the impact of functional limitations. In Canada, APE programs aim to boost fitness and well-being by customizing activities to meet individual needs. These efforts have been proven to improve muscular strength, cardiovascular endurance, flexibility, and overall health. A three-year study with adolescents who have intellectual disabilities showed lasting gains in body composition, muscular endurance, explosive strength, flexibility, and cardiovascular health (Claire, 2025). Adaptive sessions also support physical development goals and help build character (Burhaein et al., 2024). Modern, innovative approaches, especially VR technologies, are increasingly integrated into APE to enhance motivation and participation (Utamayasa et al., 2025; Posso-Pacheco et al., 2024; Norwine et al., 2025; Khasawneh, 2024). Combining VR with physical education has been shown to significantly increase interest, engagement, and enjoyment (Feng et al., 2022).

Evidence further indicates that VR is an effective coaching tool for learners with health limitations. In one study, participants aged 16–21 evaluated VR-based physical education through interviews, surveys, and observational assessments. Their responses showed a significant increase in motivation after VR sessions. Participants reported that the VR environment was engaging and beneficial for exercise. The immersive and interactive features of VR enhanced motivation and participation compared to traditional physical education (Mokmin & Rassy, 2025). Current scientific perspectives view motivation as a vital component of psychological vitality (T. N. Berezina, 2025), and VR-based adaptive physical education has been demonstrated to enhance this aspect.

Adaptive physical education delivered through VR may also help prevent future health issues in school-aged children (Roshanpour & Nikroo, 2020). VR-based programs have been shown to improve health status, enhance perceived safety (T. N. Berezina & Buzanov, 2025), and reduce the risk of traumatic stress (Skorobogatova & Margolin, 2024). Additional research has demonstrated that VR can restore mental balance, improve concentration, regulate emotional well-being, and reduce anxiety (Yin et al., 2025). Virtual reality sports training can also boost vitality, support physical development, and improve weight-related outcomes, thereby benefiting physical, psychological, and cognitive health (Wang et al., 2025). VR-based interventions have also proven effective in other vulnerable populations (T. Berezina et al., 2023).

Although research in this field is increasing, evidence on the effects of VR-based physical activity on college students' physical development remains limited.

Our study aims to fill this gap by examining physical development and vitality indicators in college students with functional health limitations compared to those without such limitations. We hypothesize that adaptive physical education with VR technologies can effectively improve functional indicators and increase overall activity levels.

2. Materials and Methods

2.1. Participants

A total of 140 college students aged 17–18 years participated in the study. The college was randomly selected from among colleges in Moscow. The sample included two groups of 70 students each.

The first group served as the comparison group and consisted of students without health limitations who were assigned to the main physical education group. These students were randomly selected from among all students without health limitations.

The second group consisted of students with mild health limitations who attended the special preparatory physical education group. In Russia, students with health limitations are typically classified into three categories for physical education: students with mild limitations attend the special preparatory group; students with moderate limitations attend special group A (health-improving); and students with more severe limitations attend special group B (rehabilitation).

At the time of the assessment, 150 college students were enrolled in the preparatory physical education group. From this population, 70 students were randomly selected to participate in the study. Placement in the special preparatory group was determined by the college's medical commission. According to the medical records, the reasons for assignment included non-endocrinological deviations in physical development, such as postural abnormalities and flat feet, mild myopia, frequent illness (three or more times per year), and recovery after illness or injury.

All students underwent a baseline assessment. The students from the preparatory group were then randomly assigned to either the experimental group ($n = 35$) or the control group ($n = 35$).

The experimental group participated in physical education classes incorporating virtual reality in small groups of 10–15 students. The control group followed the standard program established by the Federal State Educational Standard of the Russian Federation and the institutional curriculum for physical education. Students in the control group performed light exercises, attended theoretical classes, remained in the gym without active participation, or were absent for valid reasons. These activities were not specifically monitored by the research team.

All students provided voluntary informed consent to participate in the study. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Academic Council of the Faculty of Extreme Psychology at Moscow State University of Psychology and Education (28 September 2025; Protocol No. 25-26-1).

2.2. Methods for Assessing Health Indicators

1. Cardiovascular function.

Cardiovascular health was evaluated by measuring systolic and diastolic blood pressure as well as resting heart rate. According to the Clinical Guidelines "Arterial Hypertension in Children" approved by the Ministry of Health of the Russian Federation, normative values for older adolescents are:

Systolic blood pressure: 110–130 mmHg
Diastolic blood pressure: 70–85 mmHg
Resting heart rate: 65–80 beats per minute

We considered values within these limits as "corresponds to normal." Values below were considered "below normal." Values above were considered "above normal."

2. Subjective health assessment (number of reported conditions).

This measure is part of the battery used to assess biological age, as described by Voitenko and Tokar (1983). The questionnaire included 29 items that addressed various health issues. It also featured a single summary scale reflecting the number of reported conditions, with higher scores indicating poorer perceived health. The scoring system provided a quantitative self-assessment of health status:

0—excellent well-being
1–6—good
11–12—satisfactory
13–18—poor (a level considered above the normative range for older adolescents) (Nenakhova et al., 2022). We considered scores (6–12) as "Meets the norm." Scores below were considered "Below the norm." Scores above were considered "Above the norm."

2.3. Methods for Assessing Students' Physical Development

3. Static balance test.

This test measures the time (in seconds) spent balancing on one leg (left) with eyes closed. The score is independent and used in the biological age formula. The norm for older adolescents is 30 s and above. We considered scores above 30 s as "corresponds to normal." Scores below were considered "below normal."

4. Stange test.

This test measures how long (in seconds) a person voluntarily holds their breath after inhaling. The indicator has its own significance and is also included in the biological age formula. The age norm for older adolescents is 45–50 s. We considered values within this range to be "correspond to normal." Values below this range were considered "below normal." Values above this range were considered "above normal."

5. Biological age as defined by Voitenko and Tokar (Voitenko & Tokar, 1983)

Biological age was assessed using indicators from major physiological systems: cardiovascular, respiratory, vestibular (balance) function, metabolic processes, and subjective health evaluations.

The normative biological age for the studied group of older adolescents (18–19 years) is 27–28 years. Since this value exceeds their chronological age, a more useful measure is the Biological Aging Index, which is calculated as the difference between biological age and the normative biological age. Negative values indicate slower biological aging. Positive values signify faster biological aging. Values close to zero represent biologically appropriate development.

The appendix of the article (T. N. Berezina et al., 2020) includes the formulas for calculating biological age and the aging index. We considered scores within the zero range as "corresponds to normal." Scores below -1 were considered "below normal." Scores above +1 were considered "above normal."

2.4. Methods for Assessing Students' Vitality and Mindfulness

6. Mindful Attention Awareness Scale (MAAS). MAAS was developed by K. Brown and R. Ryan and was used in the Russian adaptation by A. M. Golubeva. The instrument provides a single overall score that reflects mindfulness.
7. Vitality Test (G. V. Rezapkina) includes four subscales: Life Tone, Purposefulness, Stress Resistance, and Independence. It also offers an overall Vitality Index. The tool is intended for use with adolescent populations (Rezapkina, 2017).
8. Subjective Vitality Scale (SVS). The SVS was developed by R. Ryan and C. Frederick and later translated into Russian by L. A. Aleksandrova. The scale has two components:

State Vitality (Vt-s), which measures the respondent's current, "here and now" sense of vitality.
Dispositional Vitality (Vt-d) measures a stable, characteristic level of vitality that is not tied to any moment.

2.5. Method for Assessing the Delayed Impact of Physical Activity

Delayed Impact on Physical Activity Questionnaire. The questionnaire included two questions: (1) Has your physical activity level changed in the past few months (answer options: unchanged, rather decreased, or rather increased)? (2) If it has changed, then how?

Methods of experimental intervention. We conducted physical education sessions that incorporated VR technology. Each group completed four sessions, each lasting two academic hours (1.5 h). Sessions were held once every 1–2 weeks. Each session included a brief lecture, guided discussion, physical activity, interaction with VR simulators, reflective exercises, and musical accompaniment. We used the HTC Vive virtual reality headset (HTC Corporation, Taipei Taiwan).The following VR simulators were used to organize and deliver the intervention:

Tennis simulators: VR First Person Tennis (VR First Person Tennis (independent developer Mikori Games, CA, USA), VR Racket Fury: Table Tennis (Developer: Pixel Edge Games, Żwirki i Wigury, 643-190 Mikołów, Poland).
Archery simulator: Archery Kings (Appnori Inc., Busan, Republic of Korea)

Ball-throwing simulator: VR Basketball (FG games (Fernando Gonzalez Merino), Spain, Vitoria-Gasteiz)
Shooting simulator: VR: All-in-One Sports (Appnori Inc., Busan, Republic of Korea)
Climbing simulator: The Climb 2 (Crytek, Frankfurt am Main, Germany)
Bowling and darts simulators
Training simulators: Boxing and Swimming
Volleyball and basketball simulator: All-in-One Sports application (Appnori Inc., Busan, Republic of Korea)

Classes were held at the beginning of the semester.

We conducted a delayed impact assessment at the end of the semester, three months after the end of the classes.

2.6. Statistical Analysis

(1) The Student's T-test for independent samples was used to assess differences in physical development, health and vitality between students without reported health limitations and those with such limitations. All analyses were performed on variable-specific datasets, with each indicator in a separate column. Homogeneity of variances was examined using Levene's test to determine whether the assumption of equal variances was met.
(2) The Mann–Whitney U test was applied under two conditions. First, it was used to compare health status indicators between healthy students and those with functional health limitations. The grouping variable was coded as 1 = healthy and 2 = with health limitations. Dependent variables included systolic and diastolic blood pressure, heart rate, and subjective health assessments.

Second, the test was used to evaluate baseline equivalence between the experimental and control groups before the intervention. Group membership was coded as 1 for the experimental group and 2 for the control group, and all measured indicators were treated as dependent variables.

Distributional assumptions were assessed using the Kolmogorov–Smirnov test with the Lilliefors correction. Variables that did not meet normality criteria were analyzed using nonparametric methods.

(3) Wilcoxon signed-rank tests were used to assess within-group changes over time. This included evaluating changes in the experimental group from before to after the intervention, as well as differences between the first and second assessments in the control group. These nonparametric paired analyses were selected because several indicators failed the normality assumption.
(4) We used the chi-squared test to compare age-related norms for indicators in healthy students and students with functional disabilities. This test was used only for indicators for which age norms exist. We compared whether the distribution of indicators differed between healthy students and students with disabilities. We also used this test to compare changes in physical activity between the experimental and control groups after 3 months (delayed effect).
(5) One-way ANOVA analysis of variance

Independent variable: duration of training participation. Three levels were identified.

0—No participation (student results before intervention): 35 people.

1—Incomplete training—"Low" ("Lou" is the designation for this group in the figure)—student results after attending 2–3 sessions: 25 people. Girls studying in a special physical education group were allowed to miss classes due to their menstrual cycle.

2—Complete training—"Medium"—(student results after attending all classes).

Dependent variables: indicators of physical development, health, vitality, and mindfulness. The program STATISTICA 13 was used.

Control of intervention effects was achieved through:

(1) random assignment of students to study groups; and
(2) blinded assessment of dependent variables at baseline, with partial blinding at follow-up.

Health and physical development indicators at baseline were assessed by personnel who were unaware of the participants' subsequent allocation to the control or experimental groups. At follow-up, group assignment was not communicated to the assessor; however, the assessor was not formally blinded to group allocation.

The study adhered to the ethical principles of the Declaration of Helsinki and its subsequent revisions. All participants were fully informed about the aims of the study, the procedures involved, and the voluntary nature of participation, and all provided informed consent before enrollment. Questionnaires were completed electronically, either anonymously or under a pseudonym. Results were made available to participants upon request.

All data were stored in a secure, encrypted research database. De-identified datasets are available from the authors upon reasonable request.

3. Results

First, we compared health indicators, measures of physical development, and vitality levels between students with functional health limitations and those without. The results are summarized in Table 1.

Table 1. Physical development and activity indicators for students with and without health limitations.

Indicator	Mean ± SD (Healthy Students)	Mean ± SD (Students with Limitations)	T	*p*
Static balance (s)	57.8 ± 44.18	69.5 ± 63.82	1.3	0.213
Breath-holding on inhalation (s)	55.8 ± 28.74	47.1 ± 18.87	2.1	0.038
Biological age	28.9 ± 8.90	29.0 ± 11.73	0.1	0.952
Biological aging index	1.4 ± 9.12	1.4 ± 11.93	0.1	0.954
Pulse	75.7 ± 8.78	75.6 ± 10.57	0.1	0.942
Systolic Blood Pressure	114.4 ± 10.67	113.6 ± 10.08	0.8	0.481
Diastolic Blood Pressure	74.4 ± 10.09	72.3 ± 9.17	1.5	0.174
Subjective Health Assessment (Number of diseases)	9.8 ± 4.10	11.8 ± 4.19	0.1	0.942
State vitality	31.3 ± 13.49	30.3 ± 7.06	0.4	0.727
Dispositional vitality	31.7 ± 11.13	32.9 ± 7.81	−0.4	0.672
Life tone	6.1 ± 2.47	3.37 ± 1.54	7.4	0.001
Purposefulness	5.6 ± 2.47	3.4 ± 1.60	5.9	0.001
Stress resistance	6.1 ± 2.04	3.0 ± 1.20	10.2	0.001
Independence	5.7 ± 1.60	3.3 ± 1.14	9.4	0.001
Overall vitality	23.5 ± 6.63	13.1 ± 4.00	10.5	0.001
Mindfulness	3.9 ± 1.15	3.9 ± 1.07	−0.01	0.995

T: Student's *t*-test statistic, *p*: significance level.

As shown in Table 1, students with functional health limitations differ significantly from healthy students in several indicators of subjective vitality (as measured by the G. V. Rezapkina test). Those with functional limitations demonstrated significantly lower scores in life tone (by 2.7 points, p = 0.001), purposefulness (by 2.2 points, p = 0.001), stress resistance (by 2.1 points, p = 0.001), independence (by 2.4 points, p = 0.001), and overall vitality (by 10.4 points, p = 0.001).

As shown in Table 1, there were also significant differences between students with functional health limitations and healthy students in measures of respiratory system performance. Students with functional limitations had a significantly shorter breath-holding time during inhalation than healthy students (by 8.7 s, p = 0.039). No other indicators showed significant differences.

Next, we compared whether the distribution of scores relative to age norms differed between healthy students and students with functional disabilities. To compare age-related scores for healthy students and students with functional disabilities, we used a chi-squared test. Figure 1 shows the proportion of students with scores of "Below Normal," "Corresponds to Normal," and "Above Normal."

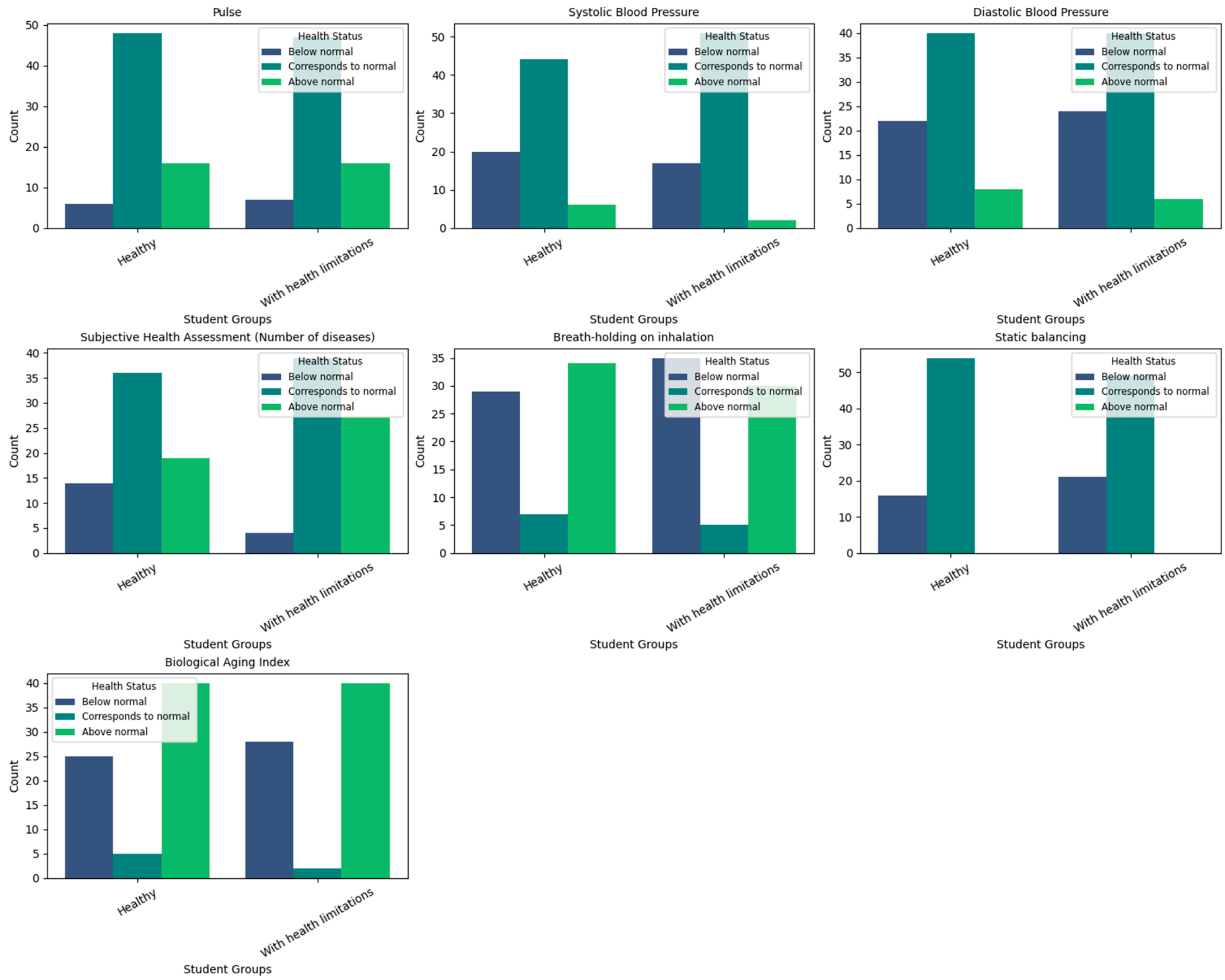

Figure 1. Distribution of physical development and activity indicators in accordance with age norms.

According to the results of the Chi-squared test, significant differences between the groups of healthy students and students with functional disabilities were observed only for the "Subjective Health Assessment (Number of diseases)" indicator, $\chi 2$ = 6.718, p = 0.035. Twenty percent (14) of healthy students considered their health to be excellent or good, compared to 6% (4) of those in the disability group. Conversely, only 27% (19) of healthy students considered their health to be poor or very poor, compared to 36% (27) of those in the disability group.

There were no significant differences for the following indicators: Pulse, Systolic Blood Pressure, Diastolic Blood Pressure, Breath-Holding on Inhalation, Static Balancing, and Biological Aging Index.

Overall, the findings from the first stage of the study indicate that there were no subjective or objective differences in general health status between students in the first and second health groups, as reflected by cardiovascular indicators. However, differences emerged in measures of physical development and vitality. Students with functional health limitations demonstrated lower values on these indicators. We believe that reduced levels of physical development and vitality may contribute to future health problems; however, with appropriate corrective interventions, these indicators can improve.

In the second stage of the study, students with functional health limitations were randomly assigned to either an experimental group or a control group. No baseline differences were identified between the groups. The results for the experimental group are presented in Table 2 and Figure 2.

Table 2. Changes in physical development, health, and vitality indicators in the experimental group before and after the intervention.

Indicator	Mean ± SD (Before)	Mean ± SD (After)	T	*p*	Effect
Pulse	75.8 ± 8.10	79.4 ± 18.26	183.0	0.456	none
Systolic BP	113.9 ± 10.42	110.7 ± 15.51	136.0	0.476	none
Diastolic BP	73.2 ± 10.21	74.0 ± 12.14	215.5	0.966	none
Body mass	57.4 ± 9.53	57.4 ± 9.66	10.5	0.554	none
Static balance	59.3 ± 55.94	79.9 ± 51.29	172.5	0.019	increases
Subjective health	11.1 ± 3.84	10.7 ± 4.29	201.0	0.964	none
Biological age	29.5 ± 10.84	24.6 ± 13.28	188.0	0.038	decreases
Biological aging index	2.1 ± 11.11	−2.7 ± 13.55	188.0	0.038	decreases
Breath-holding (s)	46.9 ± 17.12	49.6 ± 19.15	179.0	0.271	none
State vitality	30.3 ± 7.51	31.7 ± 8.94	40.5	0.268	none
Dispositional vitality	33.0 ± 7.37	33.6 ± 8.35	31.5	0.894	none
Life tone	3.4 ± 1.41	3.7 ± 1.40	9.0	0.208	none
Purposefulness	3.9 ± 1.14	4.1 ± 1.30	10.5	0.554	none
Stress resistance	2.9 ± 0.83	3.5 ± 0.93	3.5	0.042	increases
Independence	3.6 ± 1.11	3.9 ± 1.22	5.5	0.295	none
Overall vitality	13.8 ± 2.81	15.2 ± 3.08	0.01	0.011	increases
Mindfulness	3.9 ± 1.07	4.3 ± 1.05	31.5	0.006	increases

T—Wilcoxon signed-rank test statistic, *p*—significance level.

As shown in Table 2, the use of VR technologies in adaptive physical education led to a significant improvement in the static balance indicator, indicating the vestibular (balance) system's function. Additionally, both biological age and the biological aging index decreased. This is a positive result, as biological age is calculated based on health-related markers, and its reduction indicates an improvement in overall functional health.

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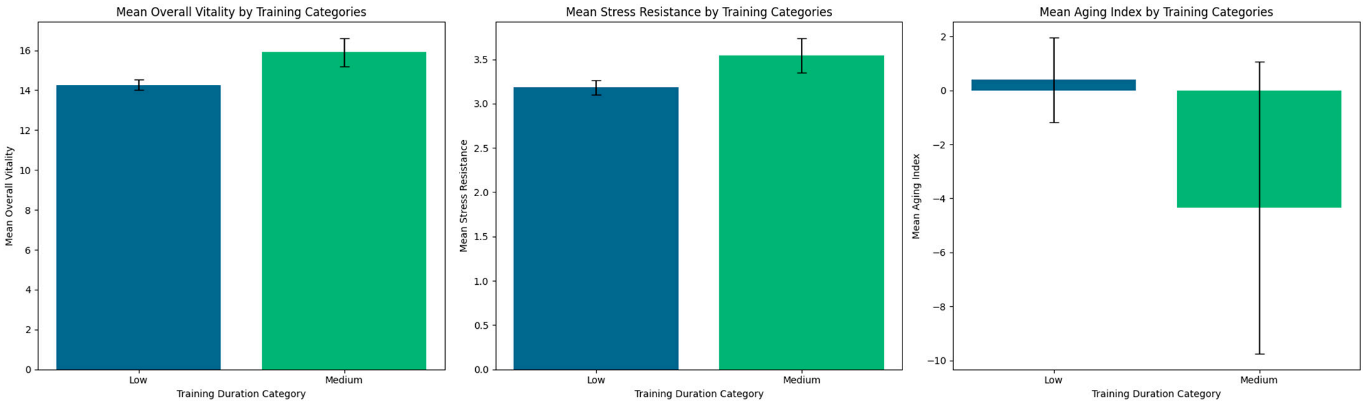

Figure 2. The influence of the duration of participation in sports VR training on activity and physical development indicators (the most significant results). *Note:* Lou—partial training, Medium—full training.

Indicators of vitality and mindfulness also increased significantly. Mindfulness, overall vitality, and stress resistance showed notable improvements. Since vitality scores for students with functional health limitations were initially lower than those of healthy peers, the post-intervention increases suggest a beneficial training effect. No significant changes were observed in the following indicators: Pulse, Systolic BP, Diastolic BP, Body mass, Subjective health, Breath-holding, State vitality, Dispositional vitality, Life tone, Purposefulness, and Independence. The results for the control group are presented in Table 3.

Table 3. Changes in physical development, health, and vitality indicators in the control group (without experimental intervention).

Indicator	Mean ± SD (Measurement 1)	Mean ± SD (Measurement 2)	T	*p*	Effect
Pulse	75.5 ±12.44	76.7 ± 12.51	212.5	0.913	none
Systolic BP	113.2 ± 9.56	115.6 ± 14.94	120.5	0.258	none
Diastolic BP	71.5 ± 7.76	74.3 ± 12.45	85.0	0.289	none
Body mass	59.6 ± 12.09	59.4 ± 12.07	50.0	0.479	none
Static balance	79.8 ± 68.56	76.3 ± 74.48	36.0	0.230	none
Subjective health	12.5 ± 4.37	12.5 ± 4.27	114.0	0.958	none
Biological age	28.5 ± 12.39	28.8 ± 14.61	251.0	0.807	none
Biological aging index	0.8 ± 12.51	1.0 ± 14.68	251.0	0.807	none
Breath-holding (s)	47.3 ± 20.23	50.0 ± 29.12	86.0	0.478	none
State vitality	30.4 ± 6.4	31.0 ± 6.7	15.0	0.374	none
Dispositional vitality	32.7 ± 8.05	33.1 ± 7.78	17.0	0.888	none
Life tone	3.3 ± 1.57	3.5 ± 1.41	5.0	0.500	none
Purposefulness	2.9 ± 1.73	3.1 ± 1.6	18.0	0.593	none
Stress resistance	3.1 ± 1.43	3.4 ± 1.45	3.0	0.115	none
Independence	3.1 ± 1.03	3.4 ± 1.21	12.0	0.400	none
Overall vitality	12.3 ± 4.59	13.3 ± 4.51	18.0	0.099	uptrend
Mindfulness	3.9 ± 0.89	3.8 + 0.83	24.0	0.239	none

T—Wilcoxon signed-rank test statistic, *p*—significance level.

As shown in Table 3, in the control group, no significant differences were observed between the first and second measurements. Overall vitality showed a non-significant trend towards an increase.

This indicates that in the control group, where students participated in adaptive physical education in the traditional format, no meaningful improvements in health status, physical development, or vitality occurred. These findings therefore support the positive impact of incorporating VR technologies into adaptive physical education.

We also examined the impact of the duration of student participation in the training (partial course (Lou) and full course (Medium)) on activity and physical development indicators using a one-way ANOVA analysis of variance. The results are presented in Figure 2.

As Figure 1 shows, duration of training significantly increases overall vitality ($F = 3.299$, $p = 0.05$) and tends to increase stress resistance ($F = 2.235$, $p = 0.1$). There is a decrease in the aging index, which does not reach significance. Duration of training has no effect on the other indicators.

An important part of our study was assessing the delayed impact of the training on physical activity. We conducted the training at the beginning of the semester, and changes in physical activity were assessed at the end of the semester for students in the experimental and control groups (using a questionnaire). Students rated their physical activity on a scale of "rather decreased," "unchanged," or "rather increased." The results are shown in Figure 3.

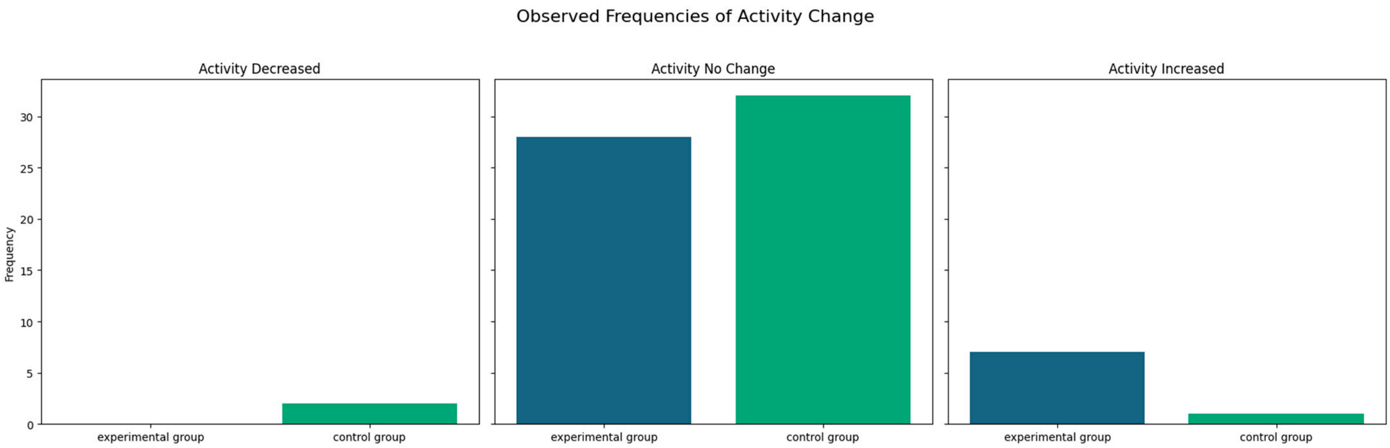

Figure 3. Students' self-assessment of changes in their physical activity 3 months after completion of the training.

As Figure 3 shows, 20% (7 people) of students in the experimental group increased their physical activity, while only 3% (1 person) of students in the control group increased their physical activity. Physical activity did not decrease in the experimental group, while it decreased in 6% (2 people) of students in the control group. The differences are significant ($\chi 2 = 6.77$, $p = 0.03$).

When asked how their physical activity changed, students responded that they "started going to the gym" (moved to the main group, attended some classes with the main group, attended some sports clubs, or went to a fitness center).

Based on these data, it can be concluded that introducing virtual sports into adaptive physical education for students with functional disabilities may, in the long term, attract students to sports activities.

4. Discussion

Our findings reveal no significant differences in the health indicators assessed between students with functional health limitations and those without. In this context, functional limitations refer to mild health issues rather than disabilities (Reuber et al., 2005). In the Russian health classification system, students with these traits are categorized under Health Group II.

This group includes individuals without chronic illnesses but who experience some functional problems. These students may often or for long periods suffer from acute respiratory infections, recover from moderate or severe infectious diseases, or have overall delays in physical growth not caused by endocrine issues, such as being short or having delayed biological development. Health Group II also covers individuals who are underweight or overweight, have minor physical deficiencies, or have lingering effects from injuries or surgeries that do not impair organ or system functions (Order of the Ministry of Health of the Russian Federation No. 514n4, 10 August 2017). Students officially categorized as having limited health capacities are also part of this group. Our study specifically focused on students in Health Group II, who therefore participate in special or adapted physical education classes.

In Russia, a doctor determines whether a student should be placed in a special physical education group based on the results of a medical exam, medical history, and reported symptoms. Placement can be temporary or permanent, depending on the nature and severity of the health condition. Students diagnosed with "limited health capacities" are also assigned to special physical education groups at the discretion of a specialized medical-pedagogical commission. A decision is made based on objective medical data, clinical history, and the student's subjective complaints. As a result, students with minor health issues who frequently seek medical care or report multiple complaints are more likely to be placed in a special physical education group, even if they do not have obvious physical impairments. Our study reflects this trend. The rising number of students identified as having mild health deviations, a pattern observed in many countries, may therefore have both objective and subjective causes. For example, a lack of motivation to participate in physical education could influence such classifications for some students.

Other researchers have also observed minimal differences between students with functional health limitations and their healthy peers. For instance, studies in the United States show that college students with non-organic functional impairments participate in physical activity at levels similar to students without such limitations (Valis & Gonzalez, 2017).

Although overall health indicators show no significant differences, the situation remains concerning. We found that students with functional limitations had lower physical development, especially in the breath-holding test that measures respiratory efficiency, and lower subjective vitality, including energy, purpose, stress resilience, independence, and overall vitality. No differences appeared in static balance duration, body mass, state vitality, or dispositional vitality. We think these differences might be temporary and due to situational factors; however, if left unaddressed, they could worsen and affect physical health over time. Much depends on how physical education programs are structured and whether instructors can motivate students and keep them engaged in physical activity. Evidence from other countries supports this view. For example, Chinese researchers have demonstrated that enhancements in functional indicators and increased physical activity are essential for improving students' overall health in adaptive physical education programs (Yang et al., 2024).

To enhance the effectiveness of adaptive physical education, our study incorporated VR technologies, an emerging method whose usefulness has been demonstrated by several researchers, including those in Russia (Shumikhina et al., 2020). We hypothesized that VR-enhanced training would increase student engagement and help students with functional limitations achieve levels closer to those of their peers without limitations. This hypothesis was confirmed: after approximately six weeks of training, students showed improvements primarily in the areas where they initially differed from healthy peers.

Health indicators remained stable, as expected, given the lack of baseline differences. However, measures of physical development improved, including those without initial disparities. For example, static balance increased, contributing to better biological age and a lower biological aging index. As is known from the literature (e.g., Simpkin et al., 2017), physical development has a greater influence on biological age in adolescence than health (unlike in older age groups). This explains the decrease in biological age after two months of training in students in the experimental group. During the training, some indicators of physical development (such as static balance) improved, which could have influenced biological age indicators. Improvements in vitality were also noted, mainly in areas where students with functional limitations initially scored below normative values. Overall vitality and stress resilience increased. Additionally, mindfulness improved, even though there were no initial group differences for this measure.

Overall, adaptive physical education supplemented with virtual sports can be considered adequate. VR-based physical activity draws on well-established psychotherapeutic principles, such as cognitive-behavioral therapy, which have repeatedly been shown to benefit students (Kaplan et al., 2023). Using these methods in VR reduces anxiety and fear among college students (Ivanova & Zavyazkina, 2025) and promotes their self-expression, engagement, and participation in adaptive physical education classes.

5. Conclusions

Developed countries have reported an increasing number of students with health limitations entering colleges and universities. The most common conditions include functional health impairments. Although these impairments do not involve serious pathology, students with such conditions are usually exempt from regular physical education classes and enrolled in adaptive physical education programs instead.

We believe that a significant portion of students attending special physical education classes have psychological rather than physical limitations. They are uninterested in sports and do not want to engage in physical activity. This may be due to negative childhood experiences with physical activity or previous illnesses that have taught them caution. Introducing them to sports on virtual simulators can help them overcome these prejudices and increase physical activity.

Our research confirmed our hypothesis.

1. In our study, no differences were found between students with functional limitations and those without limitations in cardiovascular indicators (blood pressure and heart rate) or in subjective health assessments. There were also no differences in biological age, static balancing, and awareness. The indicators (pulse, systolic blood pressure, diastolic blood pressure, breath-holding on inhalation, static balancing, and biological aging index) in students with limitations corresponded to age norms, as did the indicators in healthy students.
2. However, we did find differences in activity indicators. Students with functional disabilities had 10.4 points lower overall vitality scores (p = 0.001), and their expiratory hold time was 8.7 s shorter (p = 0.039). The distribution of the "Subjective Health Assessment (Number of Diseases)" score relative to age norms differed among students with functional disabilities compared to healthy students: they were 9% more likely to rate their health as poor or very poor and 14% less likely to rate it as good or very good (p = 0.035).

3. We implemented an intervention using VR technologies, including sports VR simulators and VR games, within adaptive physical education sessions. After the intervention, students in the experimental group demonstrated significant increases in static balance duration, overall vitality, stress resistance, and mindfulness, as well as decreases in the biological aging index. The effectiveness of the training was influenced by the number of sessions attended by students. Overall vitality increased by 2 points among students who completed the entire training ($p = 0.05$).
4. The use of VR sports simulators in physical education classes also has a delayed effect. At the end of the semester (three months after the classes), 20% of students in the experimental group showed an increase in physical activity compared to 3% of students in the control group ($p = 0.03$).

Limitations

This study included only students with mild health limitations who were assigned to the special preparatory physical education group. Students with moderate or more severe health limitations who attended health-improving or rehabilitation physical education groups were not included. Further studies are needed before these results can be extended to students with more pronounced health limitations. At the same time, this study represents an important first step, as students in the preparatory group constitute a substantial category within adaptive physical education and remain insufficiently studied in relation to VR-based interventions.

Only female students participated in this study because they constituted most of the student population. Therefore, the findings cannot be generalized to male students. Nevertheless, the study remains valuable because it provides preliminary evidence supporting the potential benefit of VR-based physical education for female students, who represented the majority of the college population.

We conducted our study only on first- and second-year female college students, who are required to take physical education classes. Our findings cannot be generalized to senior students of other age groups without further research.

We did not classify participants in the experimental group according to specific medical conditions; therefore, it remains unclear for which health conditions sports VR simulators may be most effective. The potential differential effects of the intervention across diagnostic categories remain unclear. However, the study demonstrates the feasibility and potential benefit of incorporating VR technologies into physical education for students with mild health limitations as a broader educational category.

We did not monitor the activities of students in the control group, who followed the standard physical education program established by the Federal State Educational Standard of the Russian Federation and the institutional curriculum. Therefore, the observed improvements in the experimental group may have been related to the additional classes rather than to the specific effects of the VR-based intervention.

Thus, although the findings should be interpreted with caution, the study provides important preliminary evidence supporting the feasibility and potential value of VR-based physical education for students with mild health limitations.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to ethical reasons.

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