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Age Differences in the Manifestation of Endurance Ability of Boys Karate Athletes

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Objectives. This research aims to determine the favourable age periods for endurance development among 7-11-year-old pupils who are engaged in initial karate training groups.

Materials and methods. The research involved 75 boys 7-11 years old, divided into five age groups: 7, 8, 9, 10, and 11 years old, with 15 participants per age group. The children's technical levels corresponded to the 10-9-8 Kyu (orange belt, orange with blue stripe, and blue). The children and their parents were informed about the features of the study and agreed to participate in the experiment. The study protocol was approved by the Ethics Committee of H.S. Skovoroda Kharkiv National Pedagogical University (Kharkiv, Ukraine). The following research methods were used: study and analysis of scientific and methodological literature, pedagogical observation, testing, pedagogical experiment, and methods of mathematical statistics.

Results. Statistically significant differences in the manifestation of local static power endurance of the hand muscles were observed in the groups of 7-8 and 8-9 years old ($p = 0.001$; $p = 0.007$). Differences in local dynamic power endurance of the hand muscles were found in the 8-9 years old group ($p = 0.001$), and in abdominal press endurance in the 8-9 and 9-10 years old groups ($p = 0.001$; $p = 0.01$). General cardiorespiratory endurance differences were observed in the 9-10-year-old group ($p = 0.001$). Differences in all tests between values of specified parameters in the 10-11-year-old samples were statistically insignificant ($p > 0.05$).

Conclusions. The favourable period for the development of general endurance in boys is between the ages of 8-9 and 9-10 years. At this age, it is important to start systematically and purposefully developing the aerobic abilities of pupils. Classes in the sports section of Kyokushinkai karate during extracurricular time will provide an opportunity to promote the development of general and special endurance and expand the range of motor skills.

Keywords: boys, age differences, endurance, cardiorespiratory endurance, Kyokushinkai karate.

Introduction

Endurance is considered one of the most important motor skills. It is usually associated with the ability to perform a certain activity effectively without becoming fatigued. This condition occurs when performance temporarily decreases during a given prolonged load. To continue working, individuals need to overcome fatigue. General endurance plays a significant role in optimizing vital activity, is an important component of physical health, and is, in turn, a prerequisite for the development of specific endurance (Zoladz et al., 2022; Manojlovic et al., 2023; Deng & Wang, 2024).

An analysis of studies over the past three decades has shown that low levels of cardiorespiratory endurance are associated with an increased risk of cardiovascular disease and mortality from various causes (Villa-González, Barranco-Ruiz, García-Hermoso, 2022; Manojlovic, Roklicer, Trivic et al.,

2023). Deng & Wang (2024) recommended cardiorespiratory fitness for endurance development and obesity control. Children and adolescents in the developmental stage who experience low cardiorespiratory fitness for a long time are at higher risk of cardiovascular and metabolic diseases in adulthood.

In modern studies, the authors emphasize the important role of endurance in martial arts (Kabadayı, Karadeniz, Yilmaz et al., 2022; Muñoz-Vásquez, Hernandez-Martinez, Ramos-Espinoza et al., 2023; Marchenko, Ivashchenko, Khudolii & Lubchenkov, 2023). Exercises in martial arts are intermittent by nature and include short periods of intense, maximal, and explosive movements followed by lower-intensity exercises or rest intervals for recovery (Vasconcelos et al., 2020; Ambrozy, Rydzik, Kwiatkowski et al., 2022; Marchenko, Ivashchenko, Khudolii & Lubchenkov, 2023).

It has been proven that there is a close correlation between motor competence and physical fitness in children (Luz, Rodrigues, Meester et al., 2017; Marchenko, Ivashchenko, Jagiello et



al., 2022; Marchenko, Ivashchenko & Khudolii, 2023). In contact karate, good general and special endurance is an important condition for mastering technical elements (Litvin & Marchenko, 2021; Marchenko, Ivashchenko, Jagiełło & Bobrysheva, 2023; Vako, Kashuba, Khmel'nitska et al., 2024), and for successful performances at competitions (Plush, Guppy, Nosaka et al., 2022; Ambrozy, Rydzik, Kwiatkowski et al., 2022) during certification for apprentice and master degrees. The exam usually lasts several hours and ends with fights, the number of which depends on the level of the athlete and can reach several dozen.

The scheme of fights according to the rules of Kyokushinkai karate in the 'kumite' section among younger boys and girls lasts up to 3 min (if no winner is found after the first or second round), with the following intervals: 1,0 min, 1,0 min, weigh-in, 1 min (Goncharenko, 2021; EKO Kumite rules, 2023). The time between rounds for judges to make decisions can last approximately 10-15 s, and up to 1 min during the weigh-in. With such a short break, there is no full recovery. Children perform work in a dynamic mode at high, submaximal, and maximal intensity.

The study of sensitive periods in endurance development is of great importance for both the pedagogical and sports fields. Identifying the limits of morphological readiness of different systems in children's bodies for a certain type of activity within Kyokushinkai karate allows for timely and more accurate planning of loads to achieve optimal results in the formation of endurance ability (Zymohliad & Marchenko, 2021; Konopka, Zeegers, Solberg et al., 2022; Hontarenko, Marchenko & Korol, 2022).

Considering the gender and age characteristics of pupils, it is important to remember that when working on endurance, individual deviations in body development and genetic factors should be considered. Studies have shown that aerobic and anaerobic capacities are more influenced by heredity than by the environment (Pickering & Kiely, 2019; Sellami, Elrayess, Puce et al., 2022; Konopka et al., 2022).

Sellami, Elrayess, Puce et al. (2022) pointed out that, together with the environment and training experience, an athlete's biological and genetic characteristics play an important role in exercise physiology. Heredity can be associated with an athlete's performance by influencing exercise behavior, endurance, strength, power, speed, flexibility, energy expenditure, neuromuscular coordination, metabolic and cardiorespiratory fitness, and psychological traits. Short- and long-term endurance training can improve executive function in children (Drozdowska et al., 2022; Bahtra et al., 2023; Fahrudin et al., 2024).

Given the above, the study of the peculiarities of the manifestation of various components of endurance in boys aged 7-11 years is a relevant topic.

The aim of the research is to define favorable age periods for the development of endurance in pupils aged 7-11 years who are engaged in initial karate training groups.

Materials and Methods

Participants of the Research

The research involved 75 boys in primary and secondary grades (7-11 years old). They were divided into five age groups: 7, 8, 9, 10, and 11 years old, with 15 participants per age group. The children's technical levels corresponded to the

10-9-8 Kyu (orange belt, orange with a blue stripe, and blue). The inclusion criterion was the absence of injuries within the last 3 months. The children and their parents were informed about the features of the study and agreed to participate in the experiment. The study protocol was approved by the Ethics Committee of H.S. Skovoroda Kharkiv National Pedagogical University (Kharkiv, Ukraine). This study was conducted in accordance with the Declaration of Helsinki-Ethical Principles for Medical Research Involving Human Subjects (World Medical Association Declaration of Helsinki, 2013).

Design of the Research

To solve the tasks, the following research methods were used: study and analysis of scientific and methodological literature, pedagogical observation, testing of endurance ability, pedagogical experiments, and methods of mathematical statistics.

The study was conducted during the pedagogical practice from March 4 to 29, 2024, with boys who attended the karate sports section. Training were held 3 times a week in the afternoon and lasted approximately 90 min. To determine the endurance level and identify favorable age periods for its development, testing was performed. Simple tests were chosen that did not require sophisticated equipment and were not financially expensive. A prerequisite was that the selected control exercises comprehensively covered various types of endurance: cardiorespiratory, static, and dynamic local endurance of different muscle groups.

Physical performance was assessed using the modified Harvard step test index. This test quantified the recovery processes after dosed muscle work (Hughes & Chaturvedi, 2017; White, Lu, Ibrahim et al., 2020).

Methods of the Modified Harvard Step Test: The subject walked on an 8-inch (20 cm) step for 3 min, regardless of weight and height, at a speed of 30 steps per min (one step every two s). A metronome was used to maintain the required step rate. Each movement corresponded to a single metronome beat. The Modified Harvard Step Test Index (MHSTI) was calculated using the following formula:

$$\text{MHSTI} = t \times 100 / (f_1 + f_2 + f_3) \times 2,$$

where t is the time of ascent in s; f_1 , f_2 , and f_3 are the heart rates measured at the 2nd, 3rd, and 4th min of recovery, respectively, for 30 s.

The examinations were conducted in a gym and on a sports field. The warm-up (10-15 min) consisted of simple general developmental exercises.

Statistical Analysis

The study used IBM SPSS 26 software. The following parameters were calculated: the arithmetic mean value, the standard deviation characterizing the variability of the trait (S), Student's t -test for independent samples, and Mann-Whitney U test. The hypothesis of equality of variances among the compared groups was determined using Levene's test. The threshold for statistical significance was set at $p < 0.05$.

Results

The results of statistical analysis demonstrate the peculiarities of endurance development in pupils aged 7-11 years

(Tables 1-14). At the beginning of the research, the null hypothesis regarding the equality of average values of endurance indicators among boys of all age groups was accepted. To compare the results between the study groups, the individual mean value of each parameter was calculated (Tables 1-5). Subsequently, these data were used to calculate the para-

metric Student's t-test for independent samples (Tables 6, 9, 10, 13) and the nonparametric Mann-Whitney U-test (Tables 7, 8, 11, 12, 14). Levene's test was used to compare variances between groups and to select a statistical test method.

Levene's criterion in age groups of 7-8 years old in tests "Push-ups in a lying position" ($p = .008$) and "Sit-ups in 30 s

Table 1. Statistical description of endurance indicators in 7-year-old boys

Tests	Minimum	Maximum	Average	Standard error of mean value	Standard deviation	Skewness	Standard deviation of skewness	Kurtosis	Standard error of the kurtosis
Push-ups in a lying position, times	6.0	13.0	9.6	0.542	2.098	-0.349	0.58	-0.421	1.121
Sit-ups in 30 s from the supine position, times	6.0	18.0	12.6	0.940	3.641	-0.315	0.58	-1.119	1.121
Bent arm hang, s	2.0	10.0	6.7	0.622	2.410	-0.783	0.58	-0.386	1.121
300 m run, s	92.0	128.0	108.6	2.798	10.835	0.381	0.58	-0.71	1.121
MHSTI	39.2	64.3	52.1	2.031	7.865	-0.153	0.58	-1.039	1.121

Table 2. Statistical description of endurance indicators in 8-year-old boys

Tests	Minimum	Maximum	Average	Standard error of mean value	Standard deviation	Skewness	Standard deviation of skewness	Kurtosis	Standard error of the kurtosis
Push-ups in a lying position, times	6.0	23.0	11.33	1.256	4.865	1.102	0.58	0.787	1.121
Sit-ups in 30 s from the supine position, times	10.0	20.0	14.60	0.638	2.473	0.336	0.58	0.487	1.121
Bent arm hang, s	4.50	14.60	10.53	0.725	2.809	-0.736	0.58	-0.094	1.121
300 m run, s	82.0	121.0	103.73	3.391	13.134	-0.387	0.58	-1.31	1.121
MHSTI	39.80	72.20	55.73	2.780	10.767	0.383	0.58	-1.312	1.121

Table 3. Statistical description of endurance indicators in 9-year-old boys

Tests	Minimum	Maximum	Average	Standard error of mean value	Standard deviation	Skewness	Standard deviation of skewness	Kurtosis	Standard error of the kurtosis
Push-ups in a lying position, times	11.0	27.0	18.33	1.267	4.909	0.282	0.58	-0.809	1.121
Sit-ups in 30 s from the supine position, times	12.0	25.0	19.80	0.932	3.610	-0.97	0.58	0.354	1.121
Bent arm hang, s	9.70	21.20	13.83	0.859	3.326	1.002	0.58	0.87	1.121
300 m run, s	80.0	122.0	97.40	3.722	14.416	0.558	0.58	-1.046	1.121
MHSTI	50.0	75.0	60.02	2.192	8.488	0.355	0.58	-1.067	1.121

Table 4. Statistical description of endurance indicators in 10-year-old boys

Tests	Minimum	Maximum	Average	Standard error of mean value	Standard deviation	Skewness	Standard deviation of skewness	Kurtosis	Standard error of the kurtosis
Push-ups in a lying position, times	16.0	27.0	20.9	0.894	3.461	0.344	0.58	-1.011	1.121
Sit-ups in 30 s from the supine position, times	17.0	31.0	24.0	1.187	4.598	0.102	0.58	-1.266	1.121
Bent arm hang, s	5.2	32.5	16.4	2.376	9.203	0.558	0.58	-1.082	1.121
300 m run, s	73.0	95.0	80.3	1.722	6.670	0.996	0.58	0.438	1.121
MHSTI	50.0	72.0	60.6	1.709	6.620	-0.276	0.58	-0.139	1.121

Table 5. Statistical description of endurance indicators in 11-year-old boys

Tests	Minimum	Maximum	Average	Standard error of mean value	Standard deviation	Skewness	Standard deviation of skewness	Kurtosis	Standard error of the kurtosis
Push-ups in a lying position, times	17.0	27.0	22.1	0.736	2.850	-0.411	0.58	-0.18	1.121
Sit-ups in 30 s from the supine position, times	20.0	32.0	26.1	1.093	4.234	0.018	0.58	-1.499	1.121
Bent arm hang, s	9.70	32.45	19.17	1.870	7.243	0.578	0.58	-0.745	1.121
300 m run, s	73.0	82.0	77.1	0.784	3.035	0.316	0.58	-1.125	1.121
MHSTI	50.0	72.0	58.8	1.542	5.973	0.152	0.58	0.542	1.121

Table 6. Analysis of features of manifestation of abilities to endurance of boys karate athletes of 7-8 years old

Indicators studied	Criterion for independent samples							
	Levene's criterion for equality of variance		t-test for equality of means					
	F	p	t	p	Δx	Δs	95% confidence interval for the difference	
							Lower	Upper
Push-ups in a lying position, times	8.170	0.008	-1.267	0.216	-1.733	1.368	-4.535	1.069
Sit-ups in 30 s from the supine position, times	4.499	0.043	-1.76	0.089	-2.0	1.136	-4.328	0.328
Bent arm hang, s	0.368	0.549	-4.046	0.001	-3.867	0.956	-5.824	-1.909
300 m run, s	1.180	0.287	1.107	0.278	4.867	4.396	-4.138	13.872
MHSTI	2.736	0.109	-1.061	0.298	-3.654	3.443	-10.706	3.398

Assume equal variance levels

from the supine position" ($p = 0.043$) indicates heterogeneity of dispersions ($p < 0,05$). In this case, the use of the Student's t-test for independent samples is inappropriate. Therefore, we decided to use the non-parametric Mann-Whitney U test (Tables 7, 8).

The analysis of the Mann-Whitney U-test for independent samples indicates that the distribution of the results of the tests "Push-ups in a lying position" ($p = 0.545$) and "Sit-ups in 30 s from the supine position" ($p = 0.203$) of boys aged 7-8 years is the same for these age categories. The null

hypothesis regarding the equality of groups is accepted. The differences between the values of these parameters in these samples are unreliable. Statistically significant differences between the groups according to Student's t-test were found only in the test "Bent arm hang" ($p = 0.001$).

The obtained levels of significance of empirical Student's t-criteria revealed that in groups of boys aged 8-9 years, there are statistically significant differences in most tests ($p < 0.05$). Age characteristics of children influence the level of dynamic local endurance of arm muscles and press in control exercises

Table 7. Analysis of features of manifestation of abilities to local endurance of muscles of hands of boys karate athletes of 7-8 years old

Summary of the Mann–Whitney U test for independent samples “Push-ups in a lying position”	
Total	30
Mann–Whitney U	127.0
Wilcoxon's W	247.0
Criterion statistics	127.0
Standard error	23.964
Standardised criteria statistics	0.605
Asymptotic significance (2-sided test)	0.545
Exact significance (2-sided test)	0.567

Table 8. Analysis of the peculiarities of the manifestation of abdominal muscle local endurance abilities of boys karate athletes of 7-8 years old

Summary of the Mann–Whitney U test for independent samples “Sit-ups in 30 s from the supine position”	
Total	30
Mann–Whitney U	143.0
Wilcoxon's W	263.0
Criterion statistics	143.0
Standard error	23.950
Standardised criteria statistics	1.273
Asymptotic significance (2-sided test)	0.203
Exact significance (2-sided test)	0.217

Table 9. Analysis of features of manifestation of abilities to endurance of boys karate athletes of 8-9 years old

Indicators studied	Criterion for independent samples							
	Levene's criterion for equality of variance		t-test for equality of means					
	F	p	t	p	Δx	Δs	95% confidence interval for the difference	
							Lower	Upper
Push-ups in a lying position, times	0.018	0.893	-3.923	0.001	-7.0	1.784	-10.655	-3.345
Sit-ups in 30 s from the supine position, times	1.080	0.308	-4.603	0.001	-5.2	1.130	-7.514	-2.886
Bent arm hang, s	0.036	0.850	-2.93	0.007	-3.293	1.124	-5.596	-0.991
300 m run, s	0.067	0.798	1.258	0.219	6.333	5.035	-3.981	16.648
MHSTI	1.787	0.192	-1.212	0.236	-4.291	3.540	-11.542	2.961
Assume equal variance levels								

Table 10. Analysis of features of manifestation of abilities to endurance of boys karate athletes of 9-10 years old

Indicators studied	Criterion for independent samples							
	Levene's criterion for equality of variance		t-test for equality of means					
	F	p	t	p	Δx	Δs	95% confidence interval for the difference	
							Lower	Upper
Push-ups in a lying position, times	1.776	0.193	-1.634	0.114	-2.533	1.550	-5.710	0.643
Sit-ups in 30 s from the supine position, times	1.989	0.169	-2.783	0.010	-4.20	1.509	-7.292	-1.108
Bent arm hang, s	18.429	0.000	-1.007	0.323	-2.543	2.527	-7.719	2.632
300 m run, s	9.175	0.005	4.177	0.000	17.133	4.101	8.732	25.535
MHSTI	2.152	0.154	-0.203	0.841	-0.564	2.779	-6.257	5.129
Assume equal variance levels								

Table 11. Analysis of the features of static local endurance abilities in the hand muscles of 9-10-year-old boys karate athletes

Summary of the Mann–Whitney U test for independent samples “Bent arm hang”	
Total	30
Mann–Whitney U	115.000
Wilcoxon's W	235.000
Criterion statistics	115.000
Standard error	24.106
Standardised criteria statistics	0.104
Asymptotic significance (2-sided test)	0.917
Exact significance (2-sided test)	0.935

“Push-ups in a lying position” ($p = 0.001$) and “Sit-ups in 30 s from the supine position” ($p = 0.001$). In the case of indicators of static arm muscle endurance, the average results of the

test “Bent arm hang” also differed statistically significantly ($p = 0.007$) in favor of 8-years old boys. The mean values characterizing the manifestation of cardiorespiratory endurance in the “300 m run” ($p = 0.219$) and “MHSTI” ($p = 0.236$) groups did not differ significantly ($p > 0.05$).

Statistically significant differences were revealed between samples of boys aged 9-10 years by results of tests “Sit-ups in 30 s from the supine position” ($p = 0.01$) and “300 m run” ($p < 0.001$). At the age of 10, boys demonstrate a higher level of dynamic local endurance of abdominal muscles (21.2%) and cardiorespiratory endurance (17.6%). The differences between all other values of the studied parameters in these samples were not statistically significant ($p < 0.05$).

The Mann–Whitney and Student's criteria for independent samples of boys aged 10-11 years indicate that the distribution of the results of all tests was the same for these age groups. The null hypothesis of equality of groups was confirmed. In all tests, the differences between the values of

Table 12. Analysis of the manifestation of cardiorespiratory endurance abilities in 9-10-year-old boys karate athletes

Summary of the Mann–Whitney U test for independent samples “300 m run”	
Total	30
Mann–Whitney U	26.500
Wilcoxon’s W	146.500
Criterion statistics	26.500
Standard error	24.061
Standardised criteria statistics	-3.574
Asymptotic significance (2-sided test)	0.000
Exact significance (2-sided test)	0.000

these parameters in these samples were statistically insignificant ($p > 0.05$).

Summarizing the results of the research, it is possible to state that changes in endurance development occur already in the primary school age. In this connection, it is expedient to perform the purposeful development of separate components of endurance in children aged 8, 9, and 10 years when their most intensive growth is observed.

Discussion

Physical activity (PA) aimed at developing endurance in the younger generation plays a key role in health, given the threats of the present caused by a sedentary lifestyle. It helps prevent obesity and strengthens bones, heart, and joints, thereby reducing the risk of cardiovascular disease. PA can be performed during health or sports activities.

This study demonstrated the peculiarities of the manifestation of various components of endurance abilities of boys aged 7-11 years at the stage of initial training. The study of the favorable development of these components according to age will allow preparing the functional and muscular systems of children for mastering the technical elements of karate, create favorable conditions for the manifestation of special endurance during fights at competitions and certifications, and identifying potentially gifted students inclined to this sport.

The results of this study extend and supplement the data from previous studies, which showed that introducing karate into the physical activity of schoolchildren improves the components of physical fitness (Hontarenko, Marchenko & Korol, 2022; Kabadayı, Karadeniz, Yılmaz et al., 2022; March-

Table 14. Analysis of the manifestation of cardiorespiratory endurance abilities in 10-11-year-old boys karate athletes

Summary of the Mann–Whitney U test for independent samples “300 m run”	
Total	30
Mann–Whitney U	84.0
Wilcoxon’s W	204.0
Criterion statistics	84.0
Standard error	23.972
Standardised criteria statistics	-1.189
Asymptotic significance (2-sided test)	0.234
Exact significance (2-sided test)	0.250

enko, Ivashchenko, Khudolii & Lubchenkov, 2023). Martial arts training involves work of moderate to submaximal intensity. This requires adaptive changes in the cardiovascular system, skeletal muscles, and lung ventilation (Villa-González et al., 2022; Deng & Wang, 2024).

We agree with Vasconcelos, Protzen, Galliano et al. (2020) that a more developed cardiorespiratory capacity contributes to maintaining effort during bouts through faster recovery between efforts. Various methods can contribute to the improvement of aerobic endurance (Manojlovic, Roklicer, Trivic et al., 2023).

The most common forms of martial arts are general and special exercises. General exercises: running on a treadmill or track, running with obstacles, cross-country running on rough (hilly) terrain in the forest, park, on the shore of a reservoir, skiing, and skating (Prommer, Wachsmuth, Thieme et al., 2018; Polevoy, 2023), swimming, rope jumping, cycling (Prommer, Wachsmuth, Thieme et al., 2018), sports and outdoor games (Unierzyski & Bogusławski, 2016; Marchenko, Ivashchenko, Khudolii & Lubchenkov, 2023), high-intensity interval training (HIIT) (Duncombe, Barker, Bond et al., 2022; Bauer, Sperlich, Holmberg et al., 2022; Wu, Yang, Yu et al., 2023).

Special exercises: performing striking techniques with hands and feet, various fast movements on the tatami, and around the partner, various combinations in defense with counterattacks with hands, feet, and their combinations, improving combinations under conditions of increasing mutual resistance of opponents, work with several opponents, various wrestling exercises from different positions (standing, on the ground, with a change of partners of different weight categories and heights), training on sandy soil, training in water,

Table 13. Analysis of features of manifestation of abilities to endurance of boys karate athletes of 10-11 years old

Indicators studied	Criterion for independent samples							
	Levene’s criterion for equality of variance		t-test for equality of means					
	F	p	t	p	Δx	Δs	95% confidence interval for the difference	
							Lower	Upper
Push-ups in a lying position, times	1.217	0.279	-1.094	0.283	-1.267	1.158	-3.638	1.105
Sit-ups in 30 s from the supine position, times	0.067	0.798	-1.281	0.211	-2.067	1.614	-5.372	1.239
Bent arm hang, s	1.650	0.210	-.925	0.363	-2.796	3.024	-8.991	3.397
300 m run, s	5.933	0.021	1.691	0.102	3.20	1.892	-0.676	7.076
MHSTI	0.000	0.986	0.783	0.440	1.802	2.302	-2.914	6.518
Assume equal variance levels								

special outdoor games with wrestling elements, and others (Marchenko & Satdyiev, 2021; Ambrozy, Rydzik, Kwiatkowski et al., 2022; Stamenković, Manić, Roklicer et al.).

Promoting endurance development in children and adolescents is not an easy task. They cannot overcome the fatigue caused by the central nervous system. The brain protects the body by regulating power output during any form of exercise, with the ultimate goal of maintaining homeostasis and protecting life to ensure that exercise is completed before harm occurs (Noakes, 2012). Therefore, the child's CNS is unable to activate the muscles for further action or performance at the desired level. Music, games, and competitive methods can be recommended to increase motivation. Konopka, Zeegers, Solberg et al. (2022) pointed out that it is difficult to individualize the stimulus to perform high-intensity exercises.

Although Balyi, Way, & Higgs (2013) rationale for generalized sensory periods and the scientific evidence for their existence have been criticized by Van Hooren & De Ste Croix (2020), Van Hooren & De Ste Croix (2020) stated that coaches should not rely on general sensitivity periods but rather should train all physical characteristics at all stages of development.

In our opinion, it is necessary to develop mechanisms for load correction during the development of various endurance components based on the sensitive periods and biological maturity. It is essential to pay attention to processes in physical development such as maturation with acceleration (accelerants) or lag (retardants).

Conclusions

Based on the analysis of modern scientific research, a tendency to reduce the level of physical activity in children and adolescents has been identified. A sedentary lifestyle contributes to the deterioration of motor competence and physical fitness.

Endurance is an important element in the training process, along with technical, psychological, and tactical training. The higher the level of endurance, the greater the activity potential of the body's major functions, especially respiration and circulation. The body learns several basic and applied physical skills more easily and effectively.

The results of the research indicate certain differences between boys of different age groups (7, 8, 9, 10, and 11 years). Statistically significant differences were observed in boys aged 7-8 years in the manifestation of local static power endurance, 8-9 years in local static and dynamic power endurance of the hand and abdominal muscles, and 9-10 years in dynamic power endurance of the abdominal muscles and general cardiorespiratory endurance ($p < 0.05$). Differences in all tests between the values of the specified parameters in samples of 10-11 years old are statistically unreliable ($p > 0.05$).

The favorable period for the development of general endurance in boys is between the ages of 8-9 and 9-10 years. At this age, it is important to start the systematic and purposeful development of pupils' aerobic abilities.

In our opinion, extracurricular classes in the Kyokushinkai karate sports section during extracurricular time will provide an opportunity to promote the development of general and special endurance and expand the range of motor skills. This approach will increase interest in physical activity and prevent overweight in children.

Conflict of Interest

All authors have read and approved the final version of the manuscript, and they declare no conflicts of interest.

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Вікові відмінності прояву здібності до витривалості хлопців-каратистів

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 9 с., 14 табл., 40 джерел.

Мета дослідження – визначити сприятливі вікові періоди розвитку витривалості школярів 7-11 років, які займаються у групах початкової підготовки секції карате.

Матеріали і методи. У дослідженні взяли участь 75 хлопців 7-11 років. Вони були розподілені на п'ять вікових груп: 7, 8, 9, 10 і 11 років. В кожній віковій групі було по 15 учасників. Технічний рівень дітей відповідав учнівським ступеням 10-9-8 Кю (помаранчевий колір поясу, помаранчевий із синьою смужкою та синій). Діти та їхні батьки були ознайомлені про всі особливості дослідження і дали згоду на участь в експерименті. Протокол дослідження схвалено Етичним комітетом Харківський національного педагогічного університету імені Г.С. Сковороди (Харків, Україна). Для вирішення поставлених завдань були використані методи дослідження: вивчення та аналіз науково-методичної літератури, педагогічне спостереження, тестування, педагогічний констатуючий експеримент, методи математичної статистики.

Результати. Спостерігалися статистично достовірні відмінності у прояві локальної статичної силової витривалості м'язів рук у групах 7-8, 8-9 років ($p = 0,001$; $p = 0,007$), локальної динамічної силової витривалості м'язів рук 8-9 ($p = 0,001$) і черевного пресу 8-9, 9-10 ($p = 0,001$; $p = 0,01$), загальної кардіореспіраторної витривалості 9-10 ($p = 0,001$). Відмінності за всіма тестами між значеннями вказаних параметрів у вибірках 10-11 років статистично недостовірні ($p > 0,05$).

Висновки. Сприятливим періодом для розвитку загальної витривалості хлопців є вік 8-9 і 9-10 років. У цьому віці важливо почати систематично і цілеспрямовано розвивати аеробні здібності школярів. Заняття у спортивній секції кіокушинкай карате в позаурочний час дасть можливість сприяти розвитку загальної та спеціальної витривалості, розширенню спектру рухових навичок.

Ключові слова: хлопці, вікові відмінності, витривалість, кардіореспіраторна витривалість, кіокушинкай карате.

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LaroTuro (Teaching Game Approach): Its Effectiveness on Test Performance in Araling Panlipunan (Social Studies) of Grade III Learners in Dadiangas West Central Elementary School

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Abstract

Background. Araling Panlipunan (term for Social Studies in the Philippines) is one of the subjects included in the K-12 curriculum that learners tend to find uninteresting. It is often ignored and considered as a minor subject.

Objectives. To gain insight into the problem and contribute to addressing it, this study aimed to determine the effectiveness of LaroTuro (Teaching Game Approach in the Philippines) as an intervention in improving test performance in Araling Panlipunan.

Materials and methods. Using an embedded experimental mixed-method design, twenty-eight (28) selected Grade III learners from Dadiangas West Central Elementary School participated in the study during the 2023-2024 academic year. Pre-test and post-test assessments, along with interviews, were conducted. A statistical analysis involved in carrying out the study comprised t-tests, descriptive statistics, and thematic analysis to measure the effect of the intervention.

Results. The findings revealed that before implementing the method of LaroTuro as an intervention, learners had a very low level of test performance in Araling Panlipunan due to factors like information overload, teacher-centered instruction, and limited engagement. However, after the intervention, they achieved a high level and significant enhancement in test performance, attributing to the features of the intervention such as comprehensible scope and sequence of topics, participatory game-based learning, and questioning techniques.

Conclusion. LaroTuro effectively improves the learners' test performance in Araling Panlipunan, elaborated by relationship patterns between factors and features. This research recommended conducting further studies incorporating other local games to optimize the effectiveness and practicability of LaroTuro.

Keywords: LaroTuro, test performance, Araling Panlipunan, Dadiangas West Central Elementary School.

Introduction

Social studies is a discipline that deals with human relationships and the way society works. It has been part of the basic and higher education curricula across the globe (Crisolo et al., 2021). It is met with a general perception of a broad field (Dwomoh, 2022) in which many teachers struggle with the lack of learners' interest in the content, specifically in history. This lack of interest translates into a lack of motivation to learn, so learners seem uninterested and perceive it as a boring subject (Crisolo et al., 2021). According to the most recent results of the 2022 National Assessment of Educational Progress (NAEP), only 13% of learners earned a "proficient" score in U.S. history (The Nation's Report Card, 2022; Poff, 2023). Also, few states used assessments to monitor learners' achievement in social studies (Grossman, 2023).

Torres and Tan (2019) examined the challenges faced in social studies education in the Philippines, including issues related to curriculum, teaching methods, and teacher training. Only 10% of learners in the Philippines met the minimum performance level in Araling Panlipunan (Madarang, 2021). According to the data gathered from children's academic performance, Araling Panlipunan has consistently been the lowest-performing topic in the national context, scoring only 74% on the NAT out of a possible 100% competency norm (Aguimlod et al., 2023). Learners' test results occasionally may deteriorate (Tomines et al., 2021).

The problem was apparent at Dadiangas West Central Elementary School, the examination of the secondary data has been thoroughly collected by the researchers. It has been found that 51.515 % of the Grade III learners attained low test performance in Araling Panlipunan for the 2nd grading period during the school year 2022-2023. The acquired low percentage has notified the researchers to respond to the ne-

cessities of learners as well as to provide better intervention with the aforementioned respondents.

The researchers discovered that a localized game-based learning strategy can be a potential solution to address the low level of test performance in the Araling Panlipunan given the aforementioned problem and based on the analysis of desired outcomes and opportunities. To gain insight into the problem and contribute to addressing it, a program called “LaroTuro” was designed into an instructional strategy by incorporating local games into teaching. LaroTuro originates from the Filipino words “laro” and “turo”. “Laro” translates to “play” in English, while “turo” means “teach”. Therefore, LaroTuro embodies the concept of learning through play.

Various national and international research studies have been conducted to show the effectiveness of game-based learning strategies to increase learners’ test performance. Research studies have shown that integrating learning with a game-based approach can improve learner engagement, foster greater learner investment in the course, and harmonize teachers and learners’ preferences (Scholz et al., 2021; Lee et al., 2021; Masalunga, 2021).

The purpose of this study was to determine the effectiveness of LaroTuro in improving the test performance in Araling Panlipunan of Grade III learners.

Materials and Methods

Study Subjects

This study involved the twenty-eight (28) Grade III – La-waan learners ages 8-of Dadiangas West Central Elementary School, Magsaysay Avenue, Dadiangas West, General Santos City. The data of the subjects is handled with confidentiality, and informed consent.

Design of the Study

This study employed an embedded experimental mixed-method design to evaluate the effectiveness of LaroTuro as an intervention on improving test performance in Araling Panlipunan of the learners. The research instrument used to gather quantitative data was the 30-item pre- and post-test questionnaires, it was statistically analyzed to assess the intervention’s effectiveness through analyzing the mean, standard deviation, and percentages. The assessment underwent a reliability test that showed a Guttman Split-Half Coefficient value of .711 which indicated that the instrument is reliable. The questionnaire underwent content validity by master teachers and experts in the field.

For the collection of qualitative data, researchers conducted tailored semi-structured interviews with the subjects. These interviews, both pre- and post-interview, comprised five items each, ensuring that the questions and format are age-appropriate and engaging. Each subject participated in a 16-27-minute interview session. Boese (2022) states that the average attention span of a third-grader learner is between 16 and 27 minutes. The interview questionnaire had also undergone validation by master teachers and experts in the field of social studies.

Six (6) intervention plans were made and implemented in the class for ten (10) days with four (4) sessions a week during the Araling Panlipunan class hour. It consisted of six (6) localized Filipino games in Region XII which are Tigso (Cotabato),

Karera ng Sako (Sarangani), Labay Tunga (General Santos), Sipa Tsinelas (Sultan Kudarat), Slad Sol (South Cotabato), and Stura Lata (South Cotabato). It covered lessons on the 2nd quarter of Araling Panlipunan 3 in the K-12 Basic Education Curriculum, Ang Kwento ng Lalawigan sa Ating Rehiyon.

Statistical Analysis

Descriptive statistics was used to summarize and describe the characteristics of the study subjects, as well as the pre and post-test of Araling Panlipunan. The scale below, adapted from DepEd Order No. 8 s. 2015, was employed to describe the level of test performance in Araling Panlipunan.

Numerical Range	Description	Interpretation
28-30	Outstanding	Very High
26-27	Very Satisfactory	High
24-25	Satisfactory	Moderate
22-23	Fairly Satisfactory	Low
21 and below	Did Not Meet Expectations	Very Low

Moreover, a t-test was employed in this study to examine the correlation between the independent variable which is the LaroTuro, and the dependent variable which is the test performance in Araling Panlipunan. According to Bevans (2020), to ascertain whether an intervention has an impact on the target population or whether two groups differ from one another, hypothesis testing frequently uses a t-test. The result has been tested at a 0.05 level of significance.

Furthermore, the thematic analysis was used to analyze qualitative data between the reasons for low test performance in Araling Panlipunan and the attributes of intervention. Thematic analysis is a qualitative research method that involves analyzing a set of texts, such as interview transcripts. The purpose of the analysis is to identify recurring patterns, topics, and ideas that emerge from the data. The researcher closely examines the data to identify common themes and patterns of meaning (Caulfield, 2019).

Results

Table 1. Level of Test Performance in Araling Panlipunan of the Learners before the LaroTuro was Applied

Score	f	Percentage	Description	Interpretation
28-30	0	0%	Outstanding	Very High
26-27	0	0%	Very Satisfactory	High
24-25	0	0%	Satisfactory	Moderate
22-23	0	0%	Fairly Satisfactory	Low
21 and below	28	100%	Did Not Meet Expectations	Very Low
Mean			9.07	
SD			2.78	
Description			Did Not Meet Expectations	
Interpretation			Very Low	

Table 1 presents the test performance of the learners in Araling Panlipunan before the LaroTuro was applied. The data shows that twenty-eight learners (100%) got a

score of 21 and below described as did not meet expectation. Meanwhile, none of the learners (0%) got a score of 22-23, 24-25, 26-27, and 28-30 described as fairly satisfactory, satisfactory, very satisfactory, and outstanding respectively. The table also shows that the overall mean for the pre-test is 9.07 described as did not meet expectation with a standard deviation of 2.78. This implies that the learners had a very low level of test performance in Araling Panlipunan before the LaroTuro was applied.

The Grade III learners have reached a very low level of test performance in the competency, “Nakabuo ng timeline ng mga makasaysayang pangyayari sa rehiyon sa iba’t ibang malikhaing pamamaraan”, specifically in the timeline of South Cotabato. They are having difficulty in organizing historical events in chronological order which hinders their ability to understand and connect historical events accurately. They may lack in-depth analysis or exploration of the causes, consequences, and significance of each event. Other than that, the learners were also observed to have difficulty in constructing timelines because they were not exposed to and practiced it in the first place. This means that the percentage mean score in the pre-test should improve for the LaroTuro to become significant.

Table 2 presents factors that affected the very low level of test performance of the learners before the LaroTuro was applied.

Theme 1: Information Overload. The very low level of test performance of the learners can be attributed to the information overload introduced during the Araling Panlipunan class. This factor based on the response of the learners before the LaroTuro was applied; struggles with understanding terminology and the burden of memorizing extensive

numerical data in Araling Panlipunan, ultimately leading to confusion and hesitancy in recall. This implies that the factor that contributed to the learners’ very low test performance in the Araling Panlipunan before the implementation of LaroTuro is information overload.

Theme 2: Teacher-Centered Instruction. The very low level of test performance of the learners can be attributed to the teacher-centered instruction introduced during the Araling Panlipunan class. This factor is based on the learners’ responses before the implementation of LaroTuro. Therefore, teacher-centered instruction essentially entails the teacher taking the lead and often directing learners to write, followed by memorizing timelines of events. This suggests a lack of enthusiasm from the teacher regarding the Araling Panlipunan, leaving it devoid of activities compared to other learning areas. This implies that the factor that contributed to the learners’ very low test performance in the Araling Panlipunan before the implementation of LaroTuro is the teacher-centered instruction.

Theme 3: Limited Engagement of Learners. The very low level of test performance of the learners can be attributed to the limited engagement of learners introduced during the Araling Panlipunan class. This factor based on the responses of the learners means that they experience boredom and sleepiness that diminished motivation, interest, and investment in learning. They are sometimes annoyed by their peers which hampers their ability to absorb historical concepts. So, limited engagement of learners with the Araling Panlipunan, coupled with a lack of attention and interactive activities, can weaken learners’ interest.

This implies that the factor that contributed to the learners’ very low test performance in the Araling Panlipunan before the

Table 2. Factors that Affected the Very Low Level of Test Performance of the Learners before the LaroTuro was Applied

Utterances	Code	Categories	Theme
“malimtan nako ibang lisod na words” [I tend to forget difficult words quickly]	Difficulty in word terminology	Recalling problem	Information overload
“Ahhmm... Medyo lang po, kasi maraming mga numbers e memorize” [There are many numbers to memorize]	Challenges of memorizing historical dates		
“malibog ko kay daghan dates” [I became confused because there were too many dates.]	Hesitancy	Confusion	
“Hindi sure kung tama among gibuhay nga box na may dates” [I’m not sure if the box containing the dates we created is correct.]	Uncertainty		
“opo sigeg pacopy si ma’am” [The teacher keeps us on writing.]	Writing	Content-centered instruction	Teacher-centered instruction
“AHHHMMM.... Cher sige mi memorize kanang mga dates og names” [She let us memorize those dates and the names of people.]	Memorization as a teaching method		
“nagdula mi sa MAPEH pero wala sa AP” [We played games in MAPEH but not in AP]	Less stimulating activities	Passive learning	
“wala man kaayo mi ginabuhay sa AP” [We are not doing much in AP]	Limited involvement of learners in learning		
“usahay kuan boringan ko sa subject maong mawala ko sa pokus” [Sometimes the subject bores me so I lost focus]	Boredom	Negative state of mind	Limited engagement of learners
“ahhh katulogon ko kay boring masyado” [I feel sleepy because it’s boring]	Sleepiness		
“maglagot ko kay saba si Daniel” [I get annoyed because it is too noisy when we have class]	Noisy	Disruptive behavior	
“magklase mi si Daniel sige og panguhit tas saba kaayo” [When we have class, my classmate keeps on poking and it’s annoying]	Annoyance		

implementation of LaroTuro is limited engagement. Overall, there are three (3) themes that explain the factors that cause the very low test performance in Araling Panlipunan of the learners. These themes are (1) information overload; (2) teacher-centered instruction; and (3) limited engagement of learners.

Table 3 presents the level of test performance in Araling Panlipunan of the learners after the LaroTuro was applied. The data shows that none of the learners (0%) got a score

Table 3. Level of Test Performance in Araling Panlipunan of the Learners after the LaroTuro was Applied

Score	f	Percentage	Description	Interpretation
28-30	1	3.33%	Outstanding	Very High
26-27	16	53.33%	Very Satisfactory	High
24-25	11	36.67%	Satisfactory	Moderate
22-23	0	0%	Fairly Satisfactory	Low
21 and below	0	0%	Did Not Meet Expectations	Very Low
Mean			26	
SD			1.22	
Description			Very Satisfactory	
Interpretation			High	

of 22-23, and 21 and below were described as fairly satisfactory, and did not meet expectation respectively. Eleven learners (36.67%) got a score of 24-25 described as satisfactory, sixteen learners (53.33%) got a score of 26-27 described as very satisfactory, and one learner (3.33%) got a score of 28-30 described as outstanding. The table also shows that the overall mean is 26 described as very satisfactory with a standard deviation of 1.22 generally suggests less variability and can be interpreted as greater stability. This indicates that the learners have a high level of test performance in Araling Panlipunan after the LaroTuro was applied. The learners had an improvement in constructing timelines with accuracy and critical thinking skills. It has also been observed that they understand the significant events in the timeline of South Cotabato. Thus, they can now arrange the significant events in chronological order.

Table 4 presents attributes that facilitated the high level of test performance in araling panlipunan of the learners after LaroTuro was Applied.

Theme 1: Understandable Scope and Sequence of Topics. The improved performance of learners in tests can be directly attributed to the effective implementation of an understandable scope and sequence of topics within the Araling Panlipuna. This instructional strategy facilitates better understanding

Table 4. Attributes that Facilitated the High Level of Test Performance in Araling Panlipunan of the Learners after LaroTuro was Applied

Utterances	Code	Categories	Theme
"sir, naka arranged na ang dates" [Sir, the dates are well-arranged]	Sequence		
"mas nisayon na ang AP tungod kay gi tunga-tunga man" [AP became easier because it is splitted]	Easy concept	Lesson-structured	
"...kanang nakabalo nako sa mga lisod na mga words cher sa AP. Tung dati kay di nako sya ma gets pero karon nakabalo nako kung unsa ang mga ato" [...now understand the difficult terms in AP, ma'am. Before, I couldn't grasp them, but now I know the terms]	Simple terminology	Enhance comprehension	Understandable scope and sequence of topics
"...Giganahan nako mubasa kay gamay na lang" [...I enjoyed reading because it breaks into smaller parts]	Concise topics		
"...Heheheh...ganhahan nako maminaw kay magdula man pagkahuman" [I have the motivation to listen because we will play afterwards]	Play motivates the learners to learn		
"...naa ko daan idea sa dula kay ginadula man namo siya sa among ano gud lugar tas ganahan na kaayo ko mag ano...mag ano gud... mag listen" [I already have an idea about the games because it is being played in our community. That's why I am eager to learn]	Active engagement	Game-based learning	Participatory game-based learning
"daghan, bantog ganahan nako magtabang sako grupo" [I love helping my groupmates]	Active participation		
"...teacher ganahan kaayo ko atong gidula bitaw nato na sutra lata kay tanan mi gitira" [I really enjoyed the game we played called sutra lata because all of us participated]	Enjoyment	Learning engagement	
"...naay question ginahatag during sa pagdula, tas mas maremember nako siya pag ingon atoon" [Questions are given during the game and I remember them better when they're asked like that]	Questioning during the game enhances memory recall		
"...Hmmm...kuan nakatabang ang dula sa pag answer nako sa test kay kato man gud nagdula mi kay naay question ginahatag mao tong maremember nako" [The game helped me answer the test because we acted it out and questions were provided]	Questions provided during the game help the learners answer the test	Reinforcement through questioning	Questioning technique
"Uhhh... opo sir, kay giganahan ko magtaas og kamot tapos mag tanong sa inyo" [I like it to raised my hands and start to ask]	Increased curiosity		
"nakatulong po siya cher, tapos nangutana ko kay Datu kung nagadula ba sila atong naay basket basket" [It really helped me teacher then I asked Datu if he played game basket (referring to tigso)]	Questions reveal cultural games	Problem-solving	

among learners by sequentially organizing lessons, starting from simpler concepts and gradually building up to encompass the entirety of the lesson's scope. Outlining the topics into manageable parts aids in enhancing learning outcomes and save time, particularly when content aligns with learners' knowledge and is age-appropriate. Furthermore, this instructional approach entails contextualizing the curriculum to resonate with learners' lives, environments, and cultural backgrounds. By integrating familiar themes, terminologies, and historical events that are relevant to learners' experiences. Additionally, organizing content sequentially through timelines helps learners develop a clearer understanding of historical narratives and the interconnectedness of events. This implies that the attribute that facilitated the high level of test performance in Araling Panlipunan of the learners after the LaroTuro was applied is understandable scope and sequence of topics.

Theme 2: Participatory Game-Based Learning. The improvement of the test performance of the learners can be attributed to the participatory game-based learning introduced to the learners during Araling Panlipunan class. Based on the learner's responses, it is evident that they actively participate in Araling Panlipunan through playing localized and contextualized games, such as Tigso, Stura Lata, Labay Tunga, Sipa tsinelas, Sladsol, and Karera ng Sako. This implies that the attribute that facilitated the high level of test performance in Araling Panlipunan of the learners after the LaroTuro was applied is participatory game-based learning.

Theme 3: Questioning Technique. The improvement in learners' test performance in Araling Panlipunan can be attributed to the questioning technique used within the LaroTuro intervention. This technique fosters critical thinking by encouraging learners to actively engage with the content through inquisitive exploration. It emphasizes open-ended questions to promote discussion and collaboration, while reflective questioning enhances retention and comprehension. Additionally, a metacognitive component encourages learners to consider their own thinking processes. The inclusion of culturally responsive questioning techniques ensures inclusivity, making LaroTuro a tool for deep learning in a collaborative and equitable environment. This implies that the attribute that facilitated the high level of test performance in Araling Panlipunan of the learners after the LaroTuro was applied is questioning technique.

Overall, there are three (3) themes that explain the attributes that facilitated the improvement of test performance in Araling Panlipunan of the learners. These features are (1) understandable scope and sequence of topics; (2) participatory game-based learning; and (3) questioning technique. These attributes are put together to form the LaroTuro intervention gives a result that through the ten (10) days with four (4) sessions a week, the learner's test performance can be improved. With that being observed, it was seen that the attributes of the LaroTuro as an intervention have contributed to

the improvement of the Grade III learners' test performance in Araling Panlipunan.

Table 5 presents the significant difference between the mean gained scores of the learners before and after the LaroTuro was applied. The mean gained scores of 9.07 on the pre-test and 26 on the post-test indicate that there is a significant difference in the test performance in Araling Panlipunan. The t-test analysis revealed that the computed t-value is 28.764 with a p-value of .000 which means that there is a significant difference in the mean gained scores of the pre-test and post-test scores.

The result implies that the LaroTuro is significantly effective in improving the test performance of the learners in Araling Panlipunan. Initially, the test performance of the learners before the intervention is very low however after the intervention, improvement in the test scores of the learners is evident. This means that the significant difference between the mean gained scores of the learners before the intervention can be attributed to the LaroTuro. The game may have helped the learners retain the content of the courses taught to them. LaroTuro, being a localized game-based learning strategy, specifically features Larong Pinoy helped increase the test performance of the learners in Araling Panlipunan.

Table 6. Relationship Between the Factors that Affected the Low Level of Test Performance in Araling Panlipunan and the Attributes of LaroTuro

Factors	Attributes
Information Overload	Understandable scope and sequence of topics
Teacher-Centered Instruction	Participatory Game-Based Learning
Limited Engagement of Learners	Participatory Game-Based Learning Questioning Technique

Table 6 shows the factors that affected the low level of test performance in Araling Panlipunan are information overload, teacher-centered instruction, and limited engagement of learners. In response to these factors, LaroTuro attributes are designed to improve test performance, with understandable scope and sequence of topics, participatory game-based learning, and questioning techniques. Therefore, the relationship lies in how these factors drive the development and utilization of specific attributes in LaroTuro to cater to diverse learners' needs. As a result, the attributes that the researchers used helped improve the test performance in Araling Panlipunan. Notably, the aspect of limited learner engagement is adaptable and can be effectively addressed through participatory game-based learning and questioning techniques within LaroTuro.

Discussion

This study aimed to determine the effectiveness of LaroTuro in improving the test performance in Araling Panlipunan of Grade III learners. Prior to the implementation of LaroTuro, learners exhibited a very low level of test performance in Araling Panlipunan, indicating a failure to meet expectations. This poor performance was due to information overload, limited engagement of learners, and a teacher-centered instruction, which exacerbated difficulties in construct-

Table 5. Paired t-test on the Test Performance in the Araling Panlipunan of the Learners before and after the LaroTuro was Applied

Experimental Group	Mean	SD	t	p-value	Remark
Post-test	26	1.22	28.764	0.000	Significant
Pre-test	9.07	2.78			

ing historical timelines. According to Crisolo and Camposano (2021), most learners regard Araling Panlipunan, or social studies, to be uninteresting. The literature reveals that learners exhibit a lack of interest in Araling Panlipunan, resulting in misbehavior during class discussions, a lack of motivation to learn, and failure to complete the subject's tasks (Cosme, 2019). This was supported by the study conducted by Balante et al. (2023), which stated that various factors can affect learners' interest in Araling Panlipunan. These factors include the teacher's teaching method, students' prior knowledge, and experiences, relevance of the subject to learners' lives and future, and classroom environment. Teachers and educators should consider these factors when designing and implementing effective instructional strategies and learning materials that promote the test performance in Araling Panlipunan of the learners.

Subsequently, after implementing the intervention, the learners exhibited a significantly improved performance. They attained a high level of test performance in Araling Panlipunan. This improvement can be attributed to understandable scope and sequence of topics, participatory game-based learning, and effective questioning techniques. Learners demonstrated improved accuracy and critical thinking in constructing timelines and understanding historical events. These results align with the findings of Tomines et al. (2021), who demonstrated that gamified strategies like AP-DAMA enhance learning and motivation, leading to improved academic performance.

The transition from a very low level during the pre-test to a high level in the post-test indicates a marked improvement in the learners' test performance in Araling Panlipunan following the implementation of LaroTuro. This improvement is attributed to the integration of chunking information, participatory game-based learning, and questioning techniques, which addressed the previous issues of information overload, limited engagement, and teacher-centered instruction. These strategies enhanced learners' ability to retain content, think critically, and actively engage in lessons. Similar study by Reichelt (2021) support these findings, demonstrating that gamified learning interventions significantly improve academic performance, further validating the effectiveness of LaroTuro in this context.

Moreover, many gamification studies which revealed that games contribute to the improvement of the performance of the learners. For instance, a study conducted by Aluan (2019) yielded an increase in the performance of the learners after the conduct of their gamified intervention. Francisco and Celon (2020) coined that engages the learners' interest in the topic discussed and gives an overview of the lesson they will learn and leads towards the performance of the tasks. It builds learning skills and mentions the concrete outcome or product learners are expected to demonstrate.

Conclusion

In conclusion, the study findings indicate a significant improvement in the test performance before and after the LaroTuro intervention, demonstrating that intervention effectively addressed the factors hindering the learners' success. Initially, the learners demonstrated a very low level of test performance, which was due to factors such as information overload, teacher-centered instruction, and limited student

engagement. However, after the intervention, the learners' test performance significantly improved. The key attributes of LaroTuro that contributed to this improvement include understandable scope and sequence of topics, participatory game-based learning, and questioning technique. Thus, the intervention can be considered effective in improving the test performance in Araling Panlipunan of Grade III learners.

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Conflict of Interest

The authors declare no conflicts of interest.

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LaroTuro (Ігрове навчання): ефективність застосування зазначеної методики на показники результативності тестування з Araling Panlipunan (суспільствознавства) серед учнів третього класу Дадіангаської західної центральної початкової школи

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 8 с., 6 табл., 20 джерел.

Історія питання. Araling Panlipunan (термін для позначення наукової дисципліни — суспільствознавства на Філіппінах) є одним із навчальних предметів, включених до навчальної програми К-12, який учні схильні вважати таким, що не викликає зацікавленості. Цей навчальний предмет часто не береться до уваги та розглядається як другорядна дисципліна.

Мета дослідження. Метою дослідження було визначити ефективність застосування методики LaroTuro (ігрове навчання на Філіппінах) як засобу інтервенції в контексті покращення показників результативності тестування з суспільствознавства задля глибшого розуміння проблематики та сприяння її розв'язанню.

Матеріали та методи. У дослідженні із використанням інтегрованого експериментального підходу, що базувався на змішаному методі, взяли участь двадцять вісім (28) відібраних учнів третього класу Дадіангаської західної центральної початкової школи протягом 2023-2024 навчального року. В рамках дослідження було проведено перед- та післятестове оцінювання результатів, а також здійснено опитування. З метою визначення впливу інтервенції було застосовано статистичний аналіз, що включав t-критерії, описову статистику та тематичний аналіз.

Результати. За результатами дослідження встановлено, що перед впровадженням методики ігрового навчання учні мали дуже низький рівень показників результативності тестування з суспільствознавства через такі фактори, як інформаційне перевантаження, викладацько-орієнтований підхід до навчання, а також обмежену залученість до навчального про-

цесу. Однак після проведення інтервенції учні значно поліпшили результативність тестування, досягнувши високого рівня показників успішності, що пояснюється такими особливостями інтервенції, як зрозумілий обсяг навчального матеріалу і послідовність тем, партисипативне навчання у формі ігрових елементів і використання методик проведення опитувань.

Висновки. Застосування методики ігрового навчання сприяє ефективному поліпшенню показників результативності учнів у тестуванні з суспільствознавства, що пояснюється встановленням взаємозв'язків між чинниками та особливостями навчального процесу. В рамках цієї наукової роботи рекомендовано проведення подальших досліджень із залученням інших місцевих ігор з метою оптимізації ефективності та практичної значущості ігрового навчання.

Ключові слова: ігрове навчання, результативність тестування, суспільствознавство, Дадіангаська західна центральна початкова школа.

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Assessing the Impact of Nutritional Knowledge and Information Sources on the Sports Performance of Elite Ethiopian Track Athletes: Insights for Optimized Sports Nutrition

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Abstract

Background. Proper nutrition is essential for maximizing athletic performance. Athletes with a high level of nutritional knowledge are more likely to adopt healthy dietary habits, positively impacting their performance. Understanding where athletes obtain nutritional information is crucial, as these sources influence dietary practices and performance.

Objectives. The study aimed to inform a culturally tailored nutritional strategy for Ethiopian athletes.

Materials and methods. A descriptive study was conducted with 301 randomly selected athletes from 10 sports clubs. Data on nutritional knowledge and information sources were gathered through validated questionnaires (Cronbach's alpha: 0.844 and 0.802, respectively). SPSS version 26 was used to analyze data via descriptive and inferential statistics, including correlation, regression, and ANOVA at a significance level of 0.05.

Results. The average scores for nutritional information sources and knowledge were 3.17 (SD = 1.19) and 3.09 (SD = 1.33), indicating moderate adherence. A strong correlation was found between information sources and performance ($R = 0.723$, $p < 0.001$), as well as a moderate correlation between nutritional knowledge and performance ($R = 0.629$, $p = 0.000$), explaining 79.2% of performance variance. Regression analysis showed that both factors had a significant effect on performance.

Conclusions. Nutritional knowledge and credible information sources are critical in enhancing athletes' performance. The study highlights the need for improved nutrition education among Ethiopian track athletes to promote better dietary practices and performance.

Keywords: athletes, nutritional information, nutritional knowledge, sports performance.

Introduction

Sports nutrition knowledge encompasses an understanding of nutritional factors that influence training, performance, and recovery, extending beyond general dietary knowledge. Unlike basic nutrition, which focuses on diet types and health, sports nutrition addresses the specific needs of high-performing athletes. Studies by Amawi & Alkasasbeh (2024) and Hasanpouri et al. (2023) indicate that higher nutrition knowledge correlates with better diet quality and that targeted education can improve athletes' dietary intakes (Bhawra et al., 2023; Klein et al., 2021).

For athletes, especially those in high-demand sports like track and field, nutritional knowledge (NK) is essential for sustaining health and boosting performance. Comprehensive NK equips athletes with the skills to make effective meal

choices, directly impacting performance outcomes (Vázquez-Espino et al., 2022). Studies confirm that nutrition education can improve both dietary choices and energy availability, as shown by Debnath et al. (2023) in young athletes who, after an eight-week Nutrition Education Program, increased calorie, carbohydrate, and protein intake while reducing fast-food consumption (Werner et al., 2022).

Nutrition interventions by registered dietitians have also been effective in enhancing athletes' dietary choices and body composition (Amawi & Alkasasbeh, 2024). Although some research demonstrates measurable performance improvements following nutrition education, such as increased running speed (Akman et al., 2024), results may vary based on the intervention context and athlete characteristics. Supriya's (2013) study highlights the critical role of nutritional knowledge and reliable information sources in shaping athletes' dietary choices, directly impacting their performance. Athletes with strong nutritional understanding, particularly around

macronutrient needs, hydration, and meal timing, are better positioned to support energy levels, recovery, and injury prevention. Access to accurate, science-based information from coaches, nutritionists, and credible sources promotes healthy dietary practices, while misinformation can hinder performance and increase fatigue risks. Positive attitudes toward nutrition further enhance adherence to beneficial habits, as proactive athletes seek and apply reliable guidance. Ultimately, the study suggests that structured nutrition education can foster improved dietary practices, leading to better performance outcomes and overall well-being.

Mola and Shaw (2024a) emphasize the need for managerial skills and nutrition in developing Ethiopian athletes, critiquing early specialization for its potential strains. They advocate adapting the Talent Development Environment Questionnaire for effective talent identification and underscore collaboration among sports organizations, nutritionists, and schools to provide culturally informed nutrition programs that support athletes' health and performance goals (Taye et al., 2024).

Despite their achievements in track and field, Ethiopian athletes often lack access to structured nutrition support. Studies show that athletes with higher NK make better dietary decisions, highlighting a gap in nutritional resources for Ethiopian athletes (Spronk et al., 2014). Addressing this gap with culturally relevant, science-based nutrition programs can enhance performance and serve as a model for other African countries. This study investigates the impact of nutritional knowledge, information sources, and cultural factors on the dietary practices and performance outcomes of elite Ethiopian track athletes. By examining these influences, the research aims to generate insights that inform policy and intervention frameworks, thereby supporting sustainable athletic excellence. The findings aim to inform a culturally tailored nutritional strategy for Ethiopian athletes.

Materials and Methods

Study Design and Participants

This descriptive study investigated the impact of nutritional knowledge, information sources, and athletic performance among Ethiopian track athletes. The researcher employed a standardized questionnaire developed by Rosenbloom et al. (2002) and Hasanpouri et al. (2023) to assess 301 athletes' knowledge of essential nutrition concepts – carbohydrates, proteins, fats, hydration, and micronutrients – and their perceived impact on performance. Additional items based on Hasanpouri et al. (2023) evaluated athletes' perceptions of the reliability of various nutrition information sources, including coaches, books, physicians, internet, magazines, and registered dietitians/nutritionists. Participants comprised junior and elite middle- and long-distance runners from 10 Ethiopian athletics academies, which are known for training future elite runners. Yaman's (1967) formula, with a 95% confidence interval and a 5% margin of error, determined the sample size. The final sample included 155 males (51.5%) and 146 females (48.5%) from various clubs: Sebeta Athletics Club (n = 30), Burayyu Club (n = 33), Laga Xafo Club (n = 35), Sululta Club (n = 31), Galan Club (n = 28), Dukam Club (n = 30), Holota Club (n = 17), Adama Club (n = 32), Asela Club (n = 30), and Oromia Construc-

tion Corporation (OCC) Club (n = 36). Middle- and long-distance runners who met health and physical preparedness criteria were eligible, requiring at least one year of training experience and no recent injuries. To maintain the integrity of the study, athletes participating in sprints, relay events, distances exceeding 21 km, and those with less than one year of training experience or recent injuries were excluded.

Procedure

The research utilized a descriptive survey method to examine the relationship between nutritional knowledge, sources of nutritional information, and sports performance among Ethiopian track athletes. This approach aimed to assess how these factors influence athletic performance, providing insights into the impact of both nutritional knowledge and the reliability of various information sources on athletes' outcomes. The survey employed a 28-item nutritional knowledge questionnaire and a 7-item nutritional information questionnaire, both designed for athletes, presented in a table format with a Likert scale ranging from 1 to 5. researcher systematically gathered responses from public athletic clubs in Ethiopia to gather essential data on nutritional knowledge and sources of nutritional information, to enhance athletes' performance.

Reliability and Validity of Instruments

An initial step involved evaluating the reliability and validity of each questionnaire item using Cronbach's Alpha to ensure the instrument's accuracy. The Cronbach's alpha values for the athletes' nutritional knowledge and sources of nutritional information were 0.844 and 0.802, respectively, indicating strong reliability. The instrument underwent a thorough validation process to ensure its effectiveness. Based on feedback from the pilot study, revisions were made to clarify questionnaire items and enhance their validity, reliability, and linguistic precision. The refined version was then reviewed by professional and language experts to assess its alignment with the research objectives. A subsequent pilot study with a small group of athletes, like the main participants, will test the data collection methods, confirm participant understanding, and further refine the survey instrument, following best practices in research design (Mola and Shaw, 2024b).

Statistical Analysis

The study analyzed athletes' opinions and characteristics using SPSS version 26, employing robust statistical methods. Using a five-point scale, descriptive statistics such as frequency, percentages, mean, and standard deviation were used to summarize their opinions on various dimensions. These statistics provided insights into the prevalence of each opinion, the average response, and the variability of responses, highlighting overall sentiment and consistency. To investigate potential differences, inferential statistics were applied at a significant level of 0.05. Correlation and regression analyses were used to explore the relationships between nutritional knowledge, sources of information, and sports performance. Additionally, ANOVA was employed to evaluate the predictive power of the model on performance outcomes.

Results

Demographic characteristics of the respondents

The study included 312 middle-distance and long-distance athletes who participated in regional, national, and international competitions. However, only 301 of them completed and returned the questionnaire. According to the sample size table provided by Israel (2009), this number is within the acceptable range ($301 \pm 5\%$).

Table 1. Socio-Demographic Information (n = 301)

Variable	Category	Frequency	%
Clubs name	Seбата	30	10.0
	Burayu	33	11.0
	Laga Tafo	35	11.6
	Sululta	31	10.3
	Galan	28	9.3
	Dukem	29	9.6
	Adama	32	10.6
	Holota	17	5.6
	OCC (Oromia Construction Corporation)	36	12.0
	Assela	30	10.0
	Total	301	100
Sex	Male	156	51.8
	Female	145	48.2
	Total	301	100
Age	under 18	148	49.2
	18-23	140	46.5
	24-29	13	4.3
	Total	301	100
Educational	Below high school	29	9.6
	high school	162	53.8
	Graduate	53	17.6
	College certificate & Diploma	47	15.6
	Degree	10	3.3
	Total	301	100
Marital status	Single	297	98.7
	Married	2	0.7
	Divorced	2	0.7
	Total	301	100
Monthly income	1000-2000 birr	95	31.6
	2000-4000 birr	125	41.5
	Greater than 4000 birrs	81	26.9
	Total	301	100

In terms of gender representation, 156 (51.8%) of the survey participants were male, and 145 (48.0%) were female. The gender distribution of the research sample participants is nearly equal. We asked athletes about their age and clustered the data into 4 categories, as shown in the above table. 148(49.2%) of the respondents were under 18 years, 140(46.5%) of the respondents were between 18 and 23 years, and 13(4.5%) of the respondents were between 24-29 years.

The educational background of the athletes who responded is a topic of interest. 29(9.6%) of athletes are in primary education, 162(53.8%) of athlete's respondents are high school students, 53(17.6) athletes are graduate class, 47(15.6) of the athletes were college diploma and college certified, and 10(3.3%) of the athletes were degree holders. Athletes were asked about marital status. Of the athletes, 297 (98.7) were single, 2 (0.7) married, and 2 (0.7) divorced. 95 (41.55) of the athletes earn between 2000 and 4000 birr per month, 95 (31.6%) earn between 1000 and 2000 birr per month, and the remaining 81 (26.1%) earn 4000 birr per month.

Table 2. Sports Profile of Athletes

N	Variable	Category	Frequency	%
1	Athletic Events	middle distance	190	63.1
		long distance	111	36.9
		Total	301	100
2	Races	800m	39	13.0
		1500 m	53	17.6
		3000 m steeplechase	44	14.6
		3000 m	55	18.3
		5000 m	54	17.9
		10000 m	56	18.6
		Total	301	100
3	Years Spent in the Club Since Joining	6 months -1 year	66	21.9
		1- 2 year	93	30.9
		2- 3 year	22	7.3
		3-4-year	70	23.3
		Above 5 years	50	16.6
		Total	301	100
4	Training Frequency (Train per Week)	Every day	55	18.3
		3 days per weak	105	34.9
		4 days per week	26	8.6
		5 days per week	67	22.3
		Total	301	100
5	Time of practice (training time)	only morning	126	41.9
		only afternoon	144	47.8
		both morning and afternoon	31	10.3
		Total	301	100
6	Hours of train per day	30 minutes - 1 hour	58	19.3
		1hours -1:30 hours	95	31.6
		1:30-2 hours	83	27.6
		above 2 hours	65	21.6
		Total	301	100
7	Frequency of athlete competition per year	once a year	93	30.9
		twice a year	150	49.8
		thrice a year	58	19.3
		Total	301	100
8	Level of competition	International level	70	23.3
		National level	122	40.5
		Regional level	109	36.2
		Total	301	100

Table 2 reveals that most athletes, 190 (63.1%), participate in middle-distance events, while a notable portion, 111 (36.1%), participate in long-distance events. When we delve deeper into the specific race categories, we find that

the distribution shows varying levels of participation. Notably, we categorized 39 athletes (13.0 %) under the 800m race, 53 athletes (17.6 %) under the 1500 m race, 44 athletes (14.6 %) under the 3000m steeplechase, 55 athletes (18.3 %) under the 3000 m race, 54 athletes (17.9 %) under the 5000 m race, and 56 athletes (18.6 %) under the 10000 m race. These figures highlight the versatility and specialization of middle distance in the 3000 m race and 10000 m long-distance competitors. Notably, 66 (21.9 %) for 6 months to 1 year, 93 (30.9 %) of athletes have been members for 1-2 years, 22 (7.3 %) for 2-3 years, 70 (23.3 %) for 3-4 years, and 50 (16 %) above 5 years. Examining the training frequency per week, most athletes train three days a week: 105 (34.9 %), followed by those who train five days a week: 67 (22.3 %), every day: 55 (18.3 %), and four days a week: 26 (8.6 %). The practice time reveals that 126 (41.9 %) of athletes prefer training only in the morning, 144 (47.8 %) do afternoon sessions, and 31 (10.3 %) engage in both morning and afternoon training. When considering the hours of training per day, most athletes 95 (31.6 %) train for 1 to 1:30 hours, followed by 83 (27.5 %) for 1:30 to 2 hours, 58 (19.3 %) for 30 minutes to 1 hour, and 65 (21.6 %) for above 2 hours. Regarding competition frequency per year, 150 (49.8 %) of athletes compete twice a year, 93 (30.9 %) compete once a year, and 58 (19.3 %) compete thrice a year. Finally, the level of competition showcases diversity.

Table 3. Means and Standard Deviations of Athletes' Source of Nutritional Information

N B	Athletes' Source of Nutritional Information	Mean	SD
1	The nutritional information I get from the coach is accurate.	3.50	1.15
2	The nutritional information I get from the book is reliable.	3.33	1.24
3	The nutritional information I get from physicians is accurate.	3.07	1.14
4	The nutritional information I get from the internet is reliable.	3.29	1.18
5	The Nutritional Information I get from magazines is reliable.	3.22	1.12
6	I regularly incorporate dairy products such as milk, yoghurt, or cheese into my diet.	2.58	1.32
7	The nutritional information I get from a registered dietitian/nutritionist is reliable	2.58	1.32
	Overall	3.17	1.19

The findings reveal that athletes showed moderate agreement on the accuracy of nutritional information from coaches, with a mean score of 3.50 and a standard deviation

Table 4. Means and Standard Deviations of Athletes' Nutritional Knowledge

N B	Athletes' Nutritional knowledge	Mean	SD
1	Skipping breakfast can negatively affect athletic performance.	3.08	1.27
2	Carbohydrates are the primary energy source for the body during exercise, enhancing sports performance.	3.12	1.41
3	Carbohydrates and proteins provide approximately 4 kcal per gram for fueling endurance exercise.	3.64	1.19
4	High-quality protein sources for athletes include lean meats, fish, eggs, dairy, and plant-based options.	3.14	1.38
5	Athletes require a higher protein intake than sedentary individuals to support muscle repair and growth.	3.01	1.29
6	Plant-based proteins are equally effective as animal-based proteins for muscle repair and growth.	3.70	1.12
7	Protein serves as the main energy source used by muscles during high-intensity exercise.	2.90	1.54
8	Fat intake should be minimized in an athlete's diet to optimize performance	3.00	1.31
9	Athletes should focus on consuming fats high in omega-6 fatty acids for optimal performance	3.69	1.194
10	Foods such as whole grains, fruits, vegetables, and legumes, which typically have a lower glycemic index, for better blood sugar control and sustained energy	3.10	1.166
11	Vitamins A, C, and E act as antioxidants to support overall health and immune function.	3.06	1.402
12	Vitamin D and K are primarily aided in calcium absorption, crucial for bone health.	3.77	1.070
13	Calcium deficiency can lead to stress fractures, highlighting its importance for athletes.	3.20	1.349
14	Iron deficiency can result in fatigue, injury, and illness, particularly concerning for female athletes.	3.35	1.510
15	Cheese is a good dietary source of iron, vital for energy production and performance.	2.67	1.156
16	Carrots are rich in vitamin A, essential for vision and immune function.	2.83	1.576
17	Minerals play a significant role in energy production and overall health.	3.07	1.188
18	Vitamin supplements, like Vitamin C, can help prevent upper respiratory tract infections, supporting athlete well-being.	3.48	1.165
19	During the activity, thirst is an adequate indicator of the need for fluids.	2.74	1.433
20	Athletes should consume fluids before, during, and after exercise to maintain hydration.	2.38	1.316
21	Electrolyte replacement drinks are necessary for all athletes during prolonged exercise.	2.62	1.250
22	Caffeine consumption can lead to dehydration and should be limited during exercise	2.96	1.365
23	Sodium drinks enhance fluid retention, optimizing hydration for endurance performance.	2.86	1.587
24	Endurance athletes may require daily protein drinks during the competition season.	3.41	1.519
25	Creatine supplementation, multivitamins, and iron tablets are the most effective in improving endurance.	2.98	1.210
26	Caffeine supplementation can lead to a decreased perception of effort during exercise.	3.56	1.440
27	Consumption of sodium bicarbonate can delay the onset of muscle fatigue.	3.32	1.460
28	Vitamins A, C, and E act as antioxidants to support overall health and immune function.	3.46	1.379
	Overall	3.09	1.33

SD of 1.15. The reliability of information from books received a mean score of 3.33 and an SD of 1.24, indicating a similar moderate agreement. Physicians' information received a mean rating of 3.07 and an SD of 1.14, indicating moderate accuracy. Nutritional information from the internet was considered moderately reliable, with a mean score of 3.29 and an SD of 1.18. Similarly, the reliability of information from magazines had a mean score of 3.22 and an SD of 1.12. However, information from registered dietitians/nutritionists received a lower mean score of 2.58 and an SD of 1.32, indicating less agreement among athletes about its reliability. Additionally, athletes' regular incorporation of dairy products into their diet had a mean of 2.58 and an SD of 1.32, showing variability in dietary habits. Overall, the average mean across all parameters was 3.17, with an overall SD of 1.19, suggesting a moderate level of agreement regarding the reliability of various sources of nutritional information.

The data reveals that Ethiopian athletes generally display moderate to strong agreement on various nutritional concepts. For example, athletes showed moderate agreement on the negative impact of skipping breakfast on performance (mean = 3.08, SD = 1.27) and carbohydrates as the primary energy source (mean = 3.12, SD = 1.41). There was stronger consensus on the caloric content of carbohydrates and proteins (4 kcal per gram) (mean = 3.64, SD = 1.19) and the effectiveness of plant-based proteins compared to animal-based ones for muscle growth (mean = 3.70, SD = 1.12). Athletes agreed moderately on the benefits of quality protein sources like lean meats, dairy, and eggs (mean = 3.14, SD = 1.38) and protein's role in muscle repair (mean = 3.01, SD = 1.29), but held a neutral stance on protein as the main energy source during high-intensity exercise (mean = 2.90, SD = 1.54). Similarly, there was moderate agreement on the significance of omega-6 fats (mean = 3.69, SD = 1.19) and the benefits of low-glycemic foods for sustained energy (mean = 3.10, SD = 1.17). There was a strong consensus on vitamins D and K's role in bone health (mean = 3.77, SD = 1.07), iron's importance for female athletes (mean = 3.35, SD = 1.51), and the preventive role of vitamin C against respiratory infections (mean = 3.48, standard deviation = 1.16). We recorded

Table 5. The correlation between athletes' sources of nutritional information, their nutritional knowledge, and Athlete Sports Performance

Correlations				
		SNIO	NNA	ASPEN
SNIO	Pearson Correlation	1		
	Sig. (2-tailed)			
	n	301		
NNA	Pearson Correlation	.684*	1	
	Sig. (2-tailed)	.001		
	n	301	301	
ASPEN	Pearson Correlation	.723*	.629*	1
	Sig. (2-tailed)	.001	.000	
	n	301	301	301

** . Correlation is significant at the 0.05 level (2-tailed).
SNIO: Source of Nutritional Information, NNA: Nutritional Knowledge, ASPE: Athlete Sports Performance Enhancement

neutral responses for thirst as an indicator of fluid needs (mean = 2.74, SD = 1.43), the role of caffeine in dehydration (mean = 2.96, SD = 1.37), and the benefits of electrolyte drinks during prolonged exercise (mean = 2.62, SD = 1.25). Athletes also mostly agreed that sodium bicarbonate could help reduce muscle fatigue (mean = 3.32, SD = 1.46), that caffeine supplements could help lower perceived exertion (mean = 3.56, SD = 1.44), and that daily protein drinks during the season could be helpful (mean = 3.41, SD = 1.52). In summary, athletes demonstrated varying levels of understanding across these nutritional parameters, emphasizing the need for continued education to enhance nutritional practices and optimize performance outcomes.

The survey results reveal significant correlations between several key factors and the enhancement of an athlete's sports performance. Firstly, there exists a strong positive correlation between athletes' source of nutritional information and their performance outcomes ($R = 0.723$, $p < 0.001$). These

Table 6. Effects of source of nutritional information, nutrition Knowledge on athlete's sports performance enhancement

Model Summary ^b				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.792a	.513	.658	.90064

a. Predictors: (Constant), NNA, SNIO
b. Dependent Variable: ASPEN

SNIO: Source of Nutritional Information, NNA: Nutritional Knowledge, ASPE: Athlete Sports Performance Enhancement

figures indicate a significant positive correlation between athletes' nutritional knowledge and its impact on enhancing their sports performance, with a significance level of 0.05. Furthermore, the nutritional knowledge of athletes also demonstrates a moderately positive correlation with sports performance enhancement ($R = 0.629$, $p = 0.000$). Multiple studies support this correlation, highlighting the importance of proper nutrition for optimal athletic performance. Athletes who have better nutritional knowledge tend to make more informed dietary choices, optimize their dietary intakes, and perform better in their respective sports.

As the above table depicts, the adjusted R² Value of the model is 0.792, indicating that 79.2 % of the variation in athlete sports performance enhancement is explained by the

Table 7. ANOVA of Effect on Athlete Sports Performance Enhancement

ANOVA ^a						
	Model	Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3.079	2	1.539	1.898	.000b
	Residual	241.723	298	.811		
	Total	244.801	300			

a. Dependent Variable: ASPEN
b. Predictors: (Constant), NNA, SNIO

SNIO: Source of Nutritional Information, NNA: Nutritional Knowledge, ASPE: Athlete Sports Performance Enhancement.

Table 8. Regression Coefficient

Coefficients ^a									
Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0 % Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	4.137	.381		10.855	.000	3.387	4.887		
SNIO	.196	.086	.165	1.114	.000	-.265	.073	.916	1.035
NNA	.164	.120	.180	1.366	.013	-.399	.069	.866	1.029

a. Dependent Variable: ASPEN

SNIO: Source of Nutritional Information, NNA: Nutritional Knowledge, ASPE: Athlete Sports Performance Enhancement

source of nutritional information and nutritional knowledge. In other words, 19.8 % of the variation in athlete sports performance enhancement cannot be explained by the study variables, and other factors can influence athlete sports performance enhancement.

The F-ratio in the ANOVA in the above table tests whether the overall regression model is a good fit for the data. The table shows that the independent variables statistically significantly predict the dependent variable, $F_{(2, 298)} = 1.898$, $p < .005$ (i.e., the regression model is a good fit for the data).

The values of the unstandardized beta coefficients (β) indicate the effects of each independent variable on the dependent variables. Furthermore, when all other independent variables in the models control the variance, the value of the unstandardized beta coefficients in the beta column of the above table indicates which independent variable (source of nutritional information and nutritional knowledge) makes the strongest contribution to explaining the dependent variable (effect on athlete sports performance enhancement). The t value and the sig (p) value indicate whether the independent variable is significantly contributing to the prediction of the dependent variable. The regression analysis revealed that the source of nutritional information and nutritional knowledge significantly influences the enhancement of an athlete's sports performance, with coefficients of 0.165 and 0.180, respectively. After processing multiple regressions, the following regression model was produced: Overall effect on athlete sports performance enhancement = $.381 + 0.165$ (source of nutritional information) + 0.180 (nutritional knowledge) + e

$$Y = 0.381 + 0.165X_1 + 0.180X_2 + e$$

Where Y = effect on athlete sports performance enhancement
 X_1 = Source of nutritional knowledge.
 X_2 = Nutritional knowledge
e = Sampling error

Discussion

This study aimed to investigate the influence of nutritional information sources and nutritional knowledge on the sports performance enhancement of Ethiopian track event athletes. The analysis encompassed 301 athletes from a population of 1,220, focusing on middle-distance and long-distance runners. The demographic analysis revealed a relatively balanced gender distribution (51.8 % male and 48.2 % female), a predominance of younger athletes (49.2 % under 18 years), and a significant proportion still in high school (53.8 %). Despite the prevalent high school education level among participants, this did not significantly affect

their nutritional knowledge or dietary practices. The sports profile indicated that most athletes (63.1 %) engaged in middle-distance events, trained approximately three times per week (34.9 %), and competed primarily twice a year (49.8 %). Participation occurred at various competitive levels, including national (40.5 %) and international (23.3 %). However, the data revealed that many of the respondents were in high school education, leading the researcher to assume that they might share significant ideas about nutritional knowledge, dietary intake practice, and attitude investigation. Therefore, according to Spronk et al. (2014), the level of education had no significant influence on team or individual diversion regarding nutritional knowledge, dietary intake practice, and attitude toward enhancing performance.

The study evaluated athletes' perceptions of the accuracy and reliability of various nutritional information sources. The average responses revealed a moderate level of agreement regarding the reliability of these sources. Coaches' information received a mean reliability score of 3.50, whereas books and the internet received ratings of 3.33 and 3.29, respectively. Conversely, athletes rated information from registered dietitians/nutritionists lower (mean = 2.58), indicating a lack of trust. The literature supports these findings. For example, Trakman et al. (2016) found that people often view coaches as reliable sources of nutritional information. Similarly, Torres-McGehee et al. (2012) noted that while athletes trust books and Internet sources, there remains a significant reliance on personal recommendations from coaches and physicians.

A recent study highlights the challenges faced by registered dietitians and nutritionists in building trust with athletes, often leading to decreased reliability ratings for these professionals. For instance, a study evaluating NCAA Division III collegiate athletes revealed that, despite the recognition of registered dietitians' expertise, athletes primarily relied on coaches and social media for nutrition advice, highlighting a significant trust and accessibility gap (Klein et al., 2021). Moreover, studies investigating the nutritional acumen of elite athletes indicated that many individuals had inadequate comprehension of their dietary requirements, resulting in reliance on less reputable sources rather than consulting competent nutrition experts (Hasanpour et al., 2023).

The athletes' nutritional knowledge assessment revealed moderate agreement on several key dietary concepts. Athletes demonstrated a moderate understanding of the impact of breakfast on performance (mean = 3.08), the role of carbohydrates as an energy source (mean = 3.12), and the caloric content of macronutrients (mean = 3.64). Knowledge about high-quality protein sources (mean = 3.14) and the necessity

for increased protein intake (mean = 3.01) was also moderate. However, there was a more neutral stance on the role of protein in high-intensity exercise (mean = 2.90) and the necessity of electrolyte replacement (mean = 2.62). These results align with the literature, which indicates a varied level of nutritional knowledge among athletes. For instance, Alahmadi and Albasam (2023) reported that athletes generally possess limited nutritional understanding, particularly regarding energy density and micronutrients. Conversely, Thomas et al. (2016) emphasized that a strong understanding of nutrition allows athletes to optimize their dietary intake, which enhances performance.

The study's regression analysis revealed a strong positive correlation between sources of nutritional information and sports performance enhancement ($R = 0.723$, $p < 0.001$). This supports Heaney et al. (2011) who found that athletes with comprehensive nutritional information make better dietary choices, leading to improved performance. Additionally, there is a moderate positive correlation between nutritional knowledge and sports performance enhancement ($R = 0.629$, $p = 0.000$), corroborating Akçay et al. (2023) and emphasizing the critical role of nutritional knowledge in enhancing athletic performance. The regression analysis's adjusted R^2 value of 0.792 shows that the sources of nutritional information and knowledge account for 79.2% of the variation in sports performance enhancement. This aligns with existing research, which emphasizes the critical role of nutritional information and knowledge in athletic performance. For instance, Heaney et al. (2011) conducted a systematic review and found that athletes with comprehensive nutritional information are more likely to make informed dietary choices, which directly enhance their performance. Similarly, Martín-Rodríguez et al. (2024) noted that well-informed athletes tend to optimize their dietary intakes, leading to significant improvements in their physical capabilities.

The ANOVA results ($F_{(2, 298)} = 1.898$, $p < 0.005$) confirm the regression model's validity, indicating that the sources of nutritional information and nutritional knowledge are significant predictors of sports performance enhancement. This finding is consistent with the conclusions of Thomas (2016), who emphasized that athletes with a strong understanding of nutrition can tailor their diets to optimize energy intake, recovery, and overall performance. The regression analysis also revealed that both sources of nutritional information and nutritional knowledge significantly affect sports performance enhancement, with β coefficients of 0.165 and 0.180, respectively. This indicates that while both factors are important, nutritional knowledge has a slightly stronger impact on performance enhancement. Recent literature supports the assertion that both sources of nutritional information and nutritional knowledge significantly influence sports performance enhancement (Taye et al., 2024; Reza et al., 2024). It indicates that athletes with higher levels of nutritional knowledge (NK) demonstrate better dietary habits, which are crucial for enhancing athletic performance.

The research established a positive correlation between NK and dietary practices, such as increased intake of fruits and vegetables and reduced consumption of unhealthy fats. This suggests that athletes who are better informed about nutrition can make healthier food choices that enhance their performance (Jagim et al., 2021; Vázquez-Espino et al., 2022). Mola and Shaw's (2024c) validated talent identification ques-

tionnaire enhances athlete evaluation and development, emphasizing the importance of integrating effective nutritional practices to optimize performance. The credibility and type of nutritional information sources also play a critical role. Athletes often report feeling overwhelmed by the abundance of dietary recommendations, which can lead to confusion about which advice to follow. This "information overload" can negatively impact their ability to apply nutritional knowledge effectively (Kiss et al., 2021). Conversely, athletes' understanding and application of nutritional strategies improve with well-structured educational programs that provide clear, evidence-based nutrition guidance, thereby enhancing performance outcomes (Larson-Meyer et al., 2018; Kiss et al., 2021). Research indicates that adequate nutrition is essential for optimizing physical performance and reducing injury risks among athletes. For instance, a study on collegiate athletes found significant correlations between dietary intake (including macronutrients) and performance metrics like $VO_2\text{max}$, underscoring the importance of both knowledge and proper information sources in achieving optimal performance levels (Riviere et al., 2021; Hariyanto et al., 2022).

Conclusion

This study investigated the impact of nutritional information sources and nutritional knowledge on the sports performance of Ethiopian track event athletes. The findings revealed that athletes predominantly rely on moderately reliable sources for their nutritional information, including coaches, books, physicians, and the internet, while exhibiting lower trust in registered dietitians and nutritionists. The study also highlighted that athletes possess a varied level of nutritional knowledge, with stronger agreement on certain concepts, such as the importance of carbohydrates and vitamins for performance, but more neutral or less informed stances on other areas, such as the role of protein during high-intensity exercise and the effectiveness of supplements. The results indicated a significant positive correlation between both the source of nutritional information and athletes' nutritional knowledge with sports performance enhancement. Specifically, athletes who were well-informed and relied on accurate sources of nutritional information tended to achieve better performance outcomes. The data also indicated that these factors could explain approximately 79.2% of the variation in sports performance enhancement, underscoring their significance.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Оцінка впливу обізнаності щодо принципів режиму харчування та інформаційних джерел на показники спортивної результативності елітних ефіопських легкоатлетів-бігунів: Розуміння аспектів оптимізованого спортивного харчування

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 9 с., 7 табл., 29 джерел.

Історія питання. Правильне харчування має важливе значення для забезпечення максимізації спортивної результативності. Спортсмени з високим рівнем обізнаності щодо принципів режиму харчування частіше дотримуються здорових харчових звичок, що позитивно впливає на їхні показники результативності. Розуміння шляхів отримання спортсменами інформації щодо харчування має вирішальне значення, оскільки ці джерела впливають на дієтичні практики та результативність.

Мета дослідження. Метою дослідження було надання інформації щодо стратегії харчування ефіопських спортсменів з урахуванням культурних особливостей.

Матеріали та методи. Проведено описове дослідження за участю 301 спортсменів, відібраних за методом рандомізації із 10 спортивних клубів. Збір даних щодо рівня обізнаності з питань харчування та джерел інформації здійснено за допомогою валідованих опитувальників (коефіцієнт альфа Кронбаха: 0,844 та 0,802 відповідно). Для аналізу даних використовували програмне забезпечення SPSS версії 26 за допомогою описової та інференційної статистик, включаючи кореляцію, регресію та дисперсійний аналіз (ANOVA) на рівні значущості 0,05.

Результати. Середні бали оцінки джерел інформації та обізнаності щодо аспектів харчування становили 3,17 (SD = 1,19) та 3,09 (SD = 1,33), що вказує на помірний рівень дотримання режиму харчування. Встановлено міцний кореляційний зв'язок між джерелами інформації та результативністю ($R = 0,723$, $p < 0,001$), а також помірний кореляційний зв'язок між рівнем поінформованості щодо режиму харчування та результативністю ($R = 0,629$, $p = 0,000$), що пояснює рівень дисперсії зі значенням 79,2% результативних даних. Регресійний аналіз продемонстрував, що обидва фактори мали значний вплив на показники результативності.

Висновки. Рівень обізнаності щодо режиму харчування та достовірні джерела інформації є критично важливими для підвищення результативності спортсменів. Дослідження підкреслює необхідність покращення рівня освіченості з питань харчування серед ефіопських легкоатлетів-бігунів з метою сприяння оптимізації дієтичних практик та показників результативності.

Ключові слова: спортсмени, інформація щодо харчування, обізнаність щодо харчування, спортивна результативність.

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Considering the Impact of Using Free-Body Diagram in Mechanics Problem-Solving on Improving Engineering Students' Performance in Physics at a Selected Public University in Rwanda

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Abstract

Background. Engineering students often struggle with physics problem-solving, especially mechanics problems, while teaching mechanics helps students predict motion and force impacts, enabling creative engineering design tasks. Problem-solving in mechanics involves using free-body diagrams, visual aids that identify objects and forces, determine appropriate approaches, and reduce information. The free-body diagram technique is crucial for understanding the principles of mechanics, as it helps distinguish between cause and effect, as well as focusing on the practical implementation of mechanics concepts.

Objectives. The current study aimed to examine the impact of free-body diagrams on engineering students' physics performance at a selected public university in Rwanda, highlighting cognitive load theory and constructivist learning theory's role in improving problem-solving abilities and understanding mechanics concepts.

Materials and methods. A sample of 68 students was purposively selected to participate in this study. Prior to the intervention, engineering students were given a pre-test to evaluate their ability to use free-body diagrams in solving mechanics problems. The experimental group underwent a four-week intervention, during which they were taught to draw free-body diagrams, identify external forces, and find force components. The data was collected through achievement tests and analyzed using Microsoft Excel and IBM SPSS Statistics 25.

Results. The study findings revealed that incorporating free-body diagrams into mechanics problem-solving improved significantly ($p < 0.001$) engineering students' performance in physics.

Conclusions. The study recommends incorporating free-body diagrams into the physics instructional curriculum to enhance student' understanding of basic subjects, practice problem-solving skills, and offer extra support for struggling students. Further research is needed to ascertain the impact of this approach on other physics fields.

Keywords: mechanics, engineering, problem-solving, free-body diagram.

Introduction

Engineering students frequently struggle with physics, particularly with mechanics problems, which necessitate a solid foundation in fundamental principles and problem-solving abilities (Niyomufasha et al., 2024a). Thabit et al. (2016) study shown that students who rely heavily on abstracted formulas struggle in mechanics tests due to a lack of understanding of physical concepts. The picture-like representations are more effective for understanding qualitative features of physics problems. Combining abstracted formulas and picture-like representations enhances students' learning skills and problem-solving abilities (Rosengrant et al., 2009).

Teaching and learning mechanics in physics serves a vital purpose in increasing engineering students' ability to predict the impact of motion and force, which allows students to perform creative engineering design tasks (Kraige & Meriam, 2012). Mechanics is also centered on problem-solving, and a suitable approach must be used to solve mechanics problems. Mechanics problem solving involves using representations like free-body diagrams, which are visual aids that help identify objects and forces, determine the appropriate approach, and reduce information (Taasobshirazi et al., 2022).

The free-body diagram is the most significant single step in solving mechanics problems (Thabit et al., 2016). We consider both the physical aspects of the context and the appropriate mathematical representation. Every problem requires a shift from the physical to the mathematical. A free-body diagram also is a schematic of such an isolated object that

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displays all the external forces acting upon it (Mccarthy & Goldfinch, 2010). The free-body diagram technique is essential for comprehending mechanics. This is because the isolation of an object is a technique for clearly distinguishing cause and effect and focusing our attention on the practical implementation of a mechanics concept (Kraige & Meriam, 2012).

Procedures for Drawing a Free-Body Diagram

Due to the fact that we need to account for all of the forces that are acting on the particle when formulating equilibrium equations, constructing a free-body diagram is critical (Leipold & Ivancic, 2018). The three stages required for creating a free-body diagram are as follows:

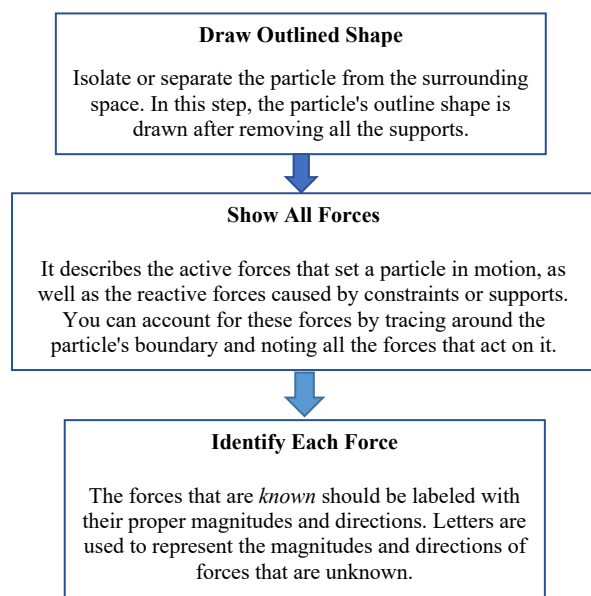


Fig. 1. Procedures for drawing free-body diagram

According to Lucas and Lewis (2019), the absence of a free-body diagram while solving mechanics problems was a common issue especially among students in engineering careers, leading to a number of analytical uncertainties. According to the theory, incorporating free-body diagrams into descriptions of problems might result in a rise, but also a decline in problem-solving challenges (Vanes et al., 2017), due to the fact that self-constructed instead of “pre-fabricated” free-body diagram are simple for students to implement as they appear to be more consistent with their own innate perceptions. It is imperative that students draw a free-body diagram correctly when trying to solve a mechanics problem because if the diagram is drawn correctly, they have a greater probability of solving the problem correctly than if the diagram is incorrect or if it is not used to solve (Rosengrant et al., 2006; Thabit et al., 2016). In order to understand mechanics, it is necessary to solve mechanics problems using free-body diagrams.

Rosengrant, Van Heuvelen, and Etkina (2009) study on physics majors found that only a small percentage of students correctly drew free-body diagrams with significant components. High-achieving students used diagrams to solve prob-

lems and evaluate their problem-solving approach, while low-achieving students drew diagrams without understanding components or checking accuracy. The study concluded that incorrect free-body diagrams led to more incorrect solutions.

Engineering and physics students have varying abilities in understanding free-body diagrams (FBDs) and solving mechanics problems. Some students understand FBDs, while others struggle due to visual or different learning levels (Davis & Lorimer, 2018).

Beyond the above studies described above, there is little research on how students are using free-body diagrams when studying or solving mechanics problems; there is a complete lack of research on engineering students’ impact on using free-body diagram in mechanics problem-solving at the University of Rwanda College of Science and Technology (UR-CST). Nguyen and Rebello (2011) found that students learn more if they understand the reason behind various pedagogical strategies such as using diagrams to solve problems. Understanding students’ free-body diagram use is an essential prerequisite to teaching students this reasoning. As a result, the purpose of this research is to explore the impact of using FBDs in mechanics problem-solving on students doing engineering for physics I’s performance. The study specifically investigated if the explicit instruction of FBDs leads to the improvement of problem-solving performance when compared to traditional approaches of teaching-learning mechanics. Finally, the findings of this study can be used to inform instructional approaches in physics education and help students improve their ability to solve mechanics problems.

FBDs, or force-based diagrams, are visual aids that help students break down complex problems into smaller parts and identify forces (Aviani et al., 2015). They also aid in understanding the connections between forces and system motions. Research shows that FBDs enhance engineering students’ understanding of physics concepts and problem-solving abilities (Mccarthy & Goldfinch, 2010; Aini, Sutopo, & Suyudi, 2021). Research has shown that employing Fundamental Differential Equations (FBDs) in mechanics problem-solving can significantly improve engineering students’ mechanics competencies. Studies by Kohl, Rosengrant and Finkelstein (2007) found that students trained in FBDs performed better on theoretical problems and numerical problems. Rosengrant et al. (2005a, 2005b) found that students taught using FBDs had a greater understanding of topics and better problem-solving abilities. Mccarthy and Goldfinch (2012) found that students using FBDs outperformed those not, and those given specific guidelines outperformed those not. Rosengrant et al. (2009) found that students using FBDs developed a stronger conceptual knowledge of physics and understood how forces interact to produce motion. Taasobshirazi and Farley (2013) found that students using FBDs were more likely to identify the necessary information and use the right equations and principles to solve problems. Overall, the evidence suggests that incorporating FBDs into mechanics classes can enhance students’ problem-solving abilities.

Theoretical Framework

The study explores the impact of free-body diagrams on engineering students’ physics performance, based on the cognitive load theory (Sweller, 1988). Free-body diagrams help

students lessen their cognitive burden by providing diagrammatic illustrations of forces acting on an item (Kirschner, 2002; Sweller, 2011). Interpreting the contents of a completed free-body diagram consumes more memory capacity than a student's step-by-step development. The intrinsic load is more noticeable in designs with force resolutions into components (Mešić, Mahmutović, Hasović, & Nataša, 2017). This study also follows the constructivist theory of learning, emphasizing active and reflective learning (Mccarthy & Goldfinch, 2012). Free-body diagrams help students become more involved with mechanics principles and gain a deeper understanding of forces' interaction with things. The research draws on physics education literature, revealing students often struggle with grasping and implementing mechanics principles. The study hypothesizes that engineering students' mechanics performance will be positively impacted by the use of free-body diagrams, particularly in improving problem-solving abilities and understanding of mechanics concepts.

Materials and methods

The primary objective of the current research is to evaluate the impact of employing free-body diagrams in mechanics problem-solving on engineering students' performance in physics. The study's goal is to see if introducing free-body diagrams into mechanics problem-solving may increase students' performance and strengthen their understanding of mechanics concepts.

Study Design and Participants

The study employed a quasi-experimental quantitative research design to assess the impact of using free-body diagram in mechanics problem-solving on engineering students' performance in physics for engineers. Prior the intervention the engineering students were give a pre-test to assess their abilities and the extent to which they were using free-body diagram in solving mechanics problems. Thereafter assessing their level in mechanics problem-solving, a four-week intervention were given to the experimental group on how to draw a free-body diagram, identifying and labeling the external forces acting on the body and affecting the motion, and finding the components of forces on x and y-axis. This intervention also included on how to apply the principles of equilibrium of forces (the sum of all forces acting on a body in equilibrium is zero, and the sum of all moments turning clockwise and sum of all moments turning counterclockwise is zero). The control group were taught using conventional method of solving physics problems without any training on how to solve mechanics problems using free-body diagram.

The study entailed assigning the same problem sets to two groups of students, with the experimental group being taught in utilizing free-body diagrams to solve mechanics problems. The experiment took place during regular classroom hours, with a final sample size of 68 pupils. The experimental group had 20 males and 14 females, whereas the control group included 24 males and 10 females. A selected sample was made by engineering students studying mechanics in year one of Electrical Power Engineering (EPE) and Electronics and Telecommunication Engineering (ETE) were

selected purposively in this study based on their will to participate into this study, their common background in secondary schools because they did the same combinations, and also they had approximately the same performance in end senior secondary exams. The students were assigned randomly into experimental and control group for the purpose of the study. Each group was composed by 34 engineering students who signed the consent to participate in this study.

In the present research, the data was collected using achievement tests (pretest and posttest). The test was composed by four mechanics problems taken from a text-book (Schaum' Outlines of College Physics, McGraw-Hill, 9th edition) that must be solved using a free-body diagram. In the pretest, neither engineering students were asked to draw a free-body diagram; nor received the instructions on drawing the free-body diagrams. One instructor marked the test for consistency and all tests questions were marked out of 20 marks, and all copies of the pre-test were used to get the information on engineering students' abilities in drawing free-body diagrams using the following codes: (0) no free-body diagrams drawn in the test; (1) all free-body diagrams drawn by the students are incorrect; (2) many of the free-body diagrams were incorrect (drawn with many errors); (3) many of free-body diagrams were drawn correctly but lacking some information (with minor errors such as force label); (4) all free-body diagrams drawn by students in solving mechanics problems were correct with all required force labels. The post-test also was given to two groups under study after training the experimental group on how to use the free-body diagrams in solving mechanics problems. The test was also marked out of 20 marks by the same instructor for maintaining consistency. Descriptive and inferential statistics were used to assess the impact of using a free-body diagram in mechanics problem-solving on engineering students' performance in physics.

Statistical Analysis

All statistical analysis was done using Microsoft Excel and IBM SPSS Statistics 25 software.

Results

The current study use a quantitative research design where pre-test were used prior the intervention and post-test after the intervention. The normality test, students' abilities in utilizing free-body diagram in mechanics problem-solving, pre-test and post-test results were presented below.

Normality test results

The normality test results by Shapiro-Wilk tests revealed that for pre-test, $p = 0.830$ and for post-test, $p = 0.782$ which were significant at the level of $p > 0.05$, means that the data were normally distributed. Therefore, the parametric test were conducted.

Students' free-body diagram abilities

Table 1 and Table 2 below represents the engineering students' abilities in drawing free-body diagram when solv-

ing mechanics problems for control and experimental group before the intervention.

Table 1. Comparison of students who drew a FBD and those did not in the control group (n = 34)

Case	Percentage
All free-body diagrams correct	8.5
All free-body diagrams incorrect	20.0
No free-body diagram drawn	55.6
Many of FBD correct	8.0
Many of FBD incorrect	7.9

In the control group, about 44.4% drew the free-body diagram where 8.5% of all free-body diagram were correct, 20.0% were incorrect, 8.0% of them, many were correct and 7.9% many of them were incorrect. The reason behind of drawing free-body diagram for some students in control group was due to their prior knowledge in mechanics problems solving from high school.

Table 2. Comparison of students who drew a FBD and those did not in the experimental group (n = 34)

Case	Percentage
All free-body diagrams correct	71.5
All free-body diagrams incorrect	5.1
No free-body diagram drawn	5.3
Many of FBD correct	11.7
Many of FBD incorrect	6.4

In the experimental group, about 94.7% drew the free-body diagram where 71.5% of all free-body diagram were correct, 5.1% were incorrect, 11.7% of them, many were correct and 6.4% many of them were incorrect. The reason behind of large number of students who was drawing free-body diagram in experimental group is due to the intervention where engineering students were trained to use free-body diagram in mechanics problems solving.

Descriptive pre- and post-test data analysis

Descriptive statistics were used to describe the characteristics of the sample. The mean and standard deviation were calculated for each group on the pre-test and post-test. The paired sample t-test was used to compare the mean scores of the pre-test and post-test within each group, and the independent samples t-test was used to compare the mean scores between the experimental and control groups. The pre-test and post-test scores of both groups were collected and analyzed using SPSS software. The descriptive statistics of the two groups are shown in Table 3.

Table 3. Descriptive Statistics of Pre-test and Post-test Scores

Group	n	Mean Pre-test	Mean Post-test	Mean Difference
Experimental	34	3.3	16.0	12.7
Control	34	2.9	7.8	4.9

Table 3 shown the mean pre-test scores of both groups had no significant difference, with experimental group scoring slightly higher (M=3.3) than control group (M=2.9). However, the mean post-test score of the experimental group

(M = 16.0) was significantly higher than the control group (M = 7.8). The mean difference between the pre-test and post-test scores of the experimental group was 12.7, which indicates a substantial improvement in their performance in mechanics problem-solving. In contrast, the mean difference between the pre-test and post-test scores of the control group was only 4.9, indicating a significant improvement in mechanics problems solving but lower than that of experimental group due to the intervention.

A paired-sample t-test was used to compare the pre-test and post-test scores of each group separately. The results are shown in Table 4.

Table 4. Paired-Sample t-Test Results

Group	t-value	df	p-value
Experimental	-23.249	33	<0.001
Control	-10.700	33	<0.001

The paired-sample t-test results in Table 4 show that the post-test scores of the experimental group were significantly higher than their pre-test scores ($t_{(34)} = -23.249$, $p < 0.001$). This indicates that the training program on FBDs had a positive impact on the performance of the experimental group. In contrast, the paired-sample t-test results for the control group show a significant difference between their pre-test and post-test scores but lower than what was obtained in experimental group ($t_{(34)} = -10.700$, $p < 0.001$). This means that the use of traditional method could affect performance but at lower level compared to the use of free-body diagram.

Pre-test results

Table 5. Independent Samples Test for pre-test results

Groups	n	Mean	SD	t	df	Sig. (2-tailed)
Control group	34	2.912	.949	-1.547	66	0.127
Experimental group	34	3.250	1.432			

Table 5 shows that the obtained p (0.127) exceeds 0.05, which implies the test does not show statistical significance at the 0.05 level, demonstrating that there were no differences that were significant between the two groups, and the null hypothesis was accepted for the pre-test. The experimental and control groups were equal before the intervention. With regards to the performance, there was no discernible difference between the experimental group (M = 3.25, SD = 1.432) and the control group (M = 2.91, SD = 0.949).

Post-test Results

Table 6. Independent Samples Test for post-test results

Groups	n	Mean	SD	t	df	Sig. (2-tailed)
Control group	34	7.809	2.7313	-11.89	66	<0.001
Experimental group	34	16.015	2.9571			

As shown in Table 6, the students who used free-body diagram in solving mechanics problems had higher achievement test scores (M = 16.015, SD = 2.957) compared to those who solved them using traditional methods of plugging

number into formulas ($M = 7.809$, $SD = 2.731$). Since the obtained p -value ($p < 0.001$) is less than 0.05, there are significant differences between the groups at 0.05 level, indicating that the experimental group has a significant advantage over the control group. As a result of this test, it is concluded that using free-body diagram in solving mechanics problems in Physics courses for Engineering College students positively affects how well they perform in physics.

Discussion

The purpose of this study was to investigate the impact of using free-body diagrams in mechanics problem solving on the performance of engineering students in physics at a selected public university in Rwanda. The use of free-body diagrams is a fundamental concept in mechanics, and its effective application is crucial for solving physics problems (McCarthy & Goldfinch, 2012). This results discussion aims to analyze and interpret the findings of the study, considering the implications for teaching and learning in physics education.

The findings of this study revealed that the use of free-body diagrams in solving mechanics problems had a significantly impacts on engineering students' performance in their first-year physics for engineers courses. During the course, students were engaged in various activities that emphasized the importance of using free-body diagram representation to enhance their understanding of the physical concepts. The experimental group ($M = 16.015$, $SD = 2.957$) results post-intervention shown that 94.7 % of students in this group drew the free-body diagram where 71.5 % of all free-body diagram were correct, 5.1 % were incorrect, 11.7 % of them, many were correct and 6.4 % many of them were incorrect. This indicates that engineering students post the intervention were aware of the importance of using free-body diagrams in solving mechanics problems, compared to the control group ($M = 7.809$, $SD = 2.731$) where 44.4 % drew the free-body diagram where 8.5 % of all free-body diagram were correct, 20.0 % were incorrect, 8.0 % of them, many were correct and 7.9 % many of them were incorrect. Those findings affirmed that students who drew correct free-body diagrams were more likely to solve problems correctly, while those who did not or drew wrong ones were unlikely to provide a correct solution (Thabit et al., 2016). This suggests that creating a correct free-body diagram would help students construct a suitable understanding of the problem, which in turn would enhance their problem-solving abilities. The current research results are consistent with other research on the impact of using free-body diagram in physics problem-solving (McCarthy & Goldfinch, 2012; Mešić, Mahmutović, Hasović, & Erceg, 2017; Rosengrant et al., 2009; Sorby & Duffy, 2022). The employment of a free-body diagram considerably improves students' chances of answering mechanics problems when compared to inaccurate free-body diagram or no diagram, emphasizing the importance of this technique in studying and mastering the area of mechanics (Niyomufasha et al., 2024b). Cognitive load is reduced through step-by-step construction of the free-body diagram, and self-constructed external representations which is more consistent and easier to interpret than those externally provided diagrams which could increase the load because they requires a higher level of metacognitive

thinking (Mešić, Mahmutović, Hasović, & Erceg, 2017). On the other hand, this study shown that the students' who did not draw free-body diagram, failed the course, which implies that students who have poor understanding of the course material are unlikely to draw free body diagrams. The success in drawing and appropriately using these diagrams is correlated to the success of a student in his/her entire course and further it indicates that the concept of drawing free-body diagrams is really fundamental. The existence of few students who could solve the test problem correctly without drawing the free-body diagram was a noticeable feature that should be considered for forthcoming research. This feature could be attributed to the fact that students who did not draw free-body diagrams may have done a correct diagram in their minds or they did it on an external draft paper which were not collected (Rosengrant et al., 2009). The analysis of the students' common mistakes in using free-body diagrams showed that students' mistakes were mainly either drawing one force (or more) in a wrong direction or wrong vector analysis of the gravitational force.

The findings of this study have important implications for teaching and learning in the context of engineering education at the University of Rwanda. Incorporating the use of free-body diagrams into physics instruction can enhance students' performance by promoting a more systematic and organized approach to problem solving. By visualizing and analyzing forces acting on an object, students develop a clearer understanding of the underlying physics concepts and principles.

Conclusion and recommendation

In conclusion, the current research aimed to evaluate the impact of using free-body diagrams in mechanics problem-solving on engineering students' performance in physics at a selected public university in Rwanda. The study discovered that students who used free-body diagrams for solving mechanics problems, not only understanding the problem statement but also creating mathematical descriptions and assessing their outcomes. This might be credited to the learning approach, which taught students how to utilize diagrams to help them comprehend concepts and solve problems. The current research also revealed that the engineering students who draw accurate free-body diagrams are more likely to answer problems properly than those who do not or draw them incorrectly. The findings show that engineering students in the experimental group are more likely to draw correct free-body diagrams as a result of the intervention, implying that these diagrams are essential for comprehending mechanics problems. In this group 94.4 % of students employed the free-body diagram approach to answer mechanics problems, even though they were not given marks for it. This indicates that students are aware of the relevance of these diagrams and have a habit of employing them to solve problems. The study found that the use of free-body diagrams in classroom work and achievement tests in the first-year engineering mechanics course greatly improves concept understanding, problem-solving abilities and their performance in physics. The study suggests the physics tutors to add free-body diagrams into their curriculum to help students comprehend basic physics subject matters. They should also provide students opportu-

nity to practice problem-solving by utilizing free-body diagrams to develop their problem-solving abilities and expertise. For some students who struggle with using free-body diagrams should be given extra help, such as mentoring or being given supplemental educational resources. To get greater insights, more study should be conducted into the influence of free-body diagrams on other physics fields, such as electrostatics or electromagnetism.

Data availability statement

The findings of this research are supported by the data available openly at the following DOI: 10.17632/56xjk7v545.1

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Conflict of interest

The authors declare no conflict of interest.

Ethical Considerations

The study adhered to ethical guidelines set by the college Research Screening and Ethics Clearance Committee (RSEC-C). The participants were informed about the purpose of the study, the data collection procedures, and their rights as participants. Participation will be voluntary, and participants were signing the consent form to approve their participation and they had the right to withdraw at any time without penalty. All data collected were kept confidential and anonymous and used for the purpose of the study only.

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APPENDIX

We provide below the four-problem assessment questions that had been solved by engineering students from the experimental and control group during pre-test and post-test. The assessment questions were the same for both pre- and post-test, the only difference was the ordering.

Problem 1

Suppose that a year one engineering student is pulling a 70kg box on a rough surface using a 400N force at an angle of 30° to the horizontal. The coefficient of kinetic friction of the box is 0.50. Find the acceleration of the box.

Problem 2

Consider the situation shown in the figure below. The uniform 0.60kN beam is hinged at P. Find the tension in the tie rope and the components of the reaction force exerted by

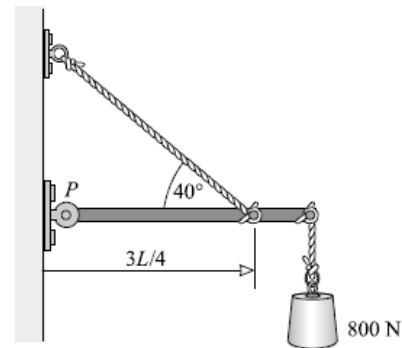


Fig 2. Illustration of Problem 2

the hinge on the beam. Given your answers to two significant figures.

Problem 3

A uniform, 0.20kN board of length has two objects hanging from it: 300N at exactly from one end, and 400N at exactly from the same end. What single additional force acting on the board will cause the board to be in equilibrium?

Problem 4

Approximately what magnitude of force, F_M , must the extensor muscle in the upper arm exert on the lower arm to hold a 7.3 kg shot put? Assume the lower arm has a mass of 2.8 kg and its CG is 12 cm from the elbow-joint pivot.

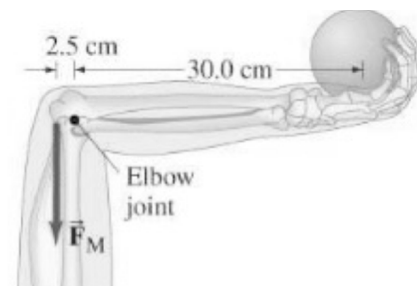


Fig 2. Illustration of Problem 4

Розгляд впливу використання діаграми вільного тіла при розв'язуванні задач з механіки на покращення показників успішності з фізики студентів інженерних спеціальностей окремого державного університету в Руанді

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 8 с., 6 табл., 3 рис., 26 джерел.

Історія питання. Студенти інженерних спеціальностей часто стикаються з труднощами в процесі розв'язування задач з фізики, особливо з механіки, тоді як вивчення механіки допомагає студентам прогнозувати рух і силові впливи, що сприяє виконанню творчих завдань з інженерного проектування. Розв'язування задач з механіки передбачає

використання діаграм вільного тіла, візуальних засобів, які ідентифікують об'єкти та сили, визначають відповідні підходи та зменшують обсяг інформації. Техніка діаграми вільного тіла має ключове значення в контексті розуміння принципів механіки, оскільки допомагає розрізняти причину і наслідок, а також зосередитися на практичному застосуванні механічних концепцій.

Мета дослідження. Мета цього дослідження полягала у вивченні впливу використання діаграм вільного тіла на показники успішності з фізики студентів інженерних спеціальностей окремого державного університету в Руанді, підкреслюючи роль теорії когнітивного навантаження та конструктивістської теорії навчання щодо поліпшення здатності застосовувати набуті знання і вміння до розв'язування задач та розуміння концепцій механіки.

Матеріали та методи. До участі в дослідженні було цілеспрямовано залучено вибірку із 68 студентів. Перед початком інтервенції студенти інженерних спеціальностей пройшли попередній тест з метою оцінки їхньої здатності використовувати діаграми вільного тіла при розв'язуванні задач з механіки. Експериментальна група проходила чотиритижневий курс інтервенції, під час якого їх вчили креслити діаграми вільного тіла, визначати зовнішні сили та знаходити силові компоненти. Збір даних здійснено за допомогою тестів досягнень та проаналізовано із застосуванням програмного забезпечення Microsoft Excel та IBM SPSS Statistics 25.

Результати. За результатами дослідження встановлено, що включення діаграм вільного тіла до розв'язування задач з механіки сприяло суттєвому ($p < 0,001$) покращенню показників успішності студентів інженерних спеціальностей з фізики.

Висновки. Дослідження рекомендує включати використання діаграм вільного тіла до навчальної програми з фізики задля підвищення розуміння студентами базових тем, відпрацювання навичок розв'язування задач і надання додаткової підтримки студентам, які мають труднощі з навчанням. Проведення подальших досліджень слід спрямувати на з'ясування впливу зазначеного підходу на інші галузі фізики.

Ключові слова: механіка, інженерія, розв'язування задач, діаграма вільного тіла.

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Determining the Validity and Reliability of ArtSci-S.P.D. Module on Year 5 Human Circulatory System

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Objectives. The study aimed to determine the validity and reliability of the developed art-integration in science learning module, named ArtSci-S.P.D. Implementing the module has been carried out in order to ensure its suitability for using in further research.

Materials and methods. The analysis approach for face validity was Fleiss' kappa, while the content validity index (CVI) was employed to assess content validity, and the test-retest reliability method was used for measuring reliability. The calculation of test-retest reliability was performed by using Pearson's correlation coefficient.

Results. The findings show a positive tendency for evaluating the face and content validity (Fleiss' kappa, $k = 0.66$; $CVI > 0.78$). Additionally, the module exhibits a high coefficient of reliability ($r = 0.87$).

Conclusions. Thus, the module has been considered to be a valid and reliable tool for using in the actual study, thereby underscoring its efficacy.

Keywords: science-art integration, learning module, validity, reliability, test-retest reliability, Pearson's correlation.

Introduction

Science is an interesting and fun subject which is provided from primary school that should be learned by the students from the time they are young until the university level. In Malaysia, enrollment of science learning is gradually decreasing as there are some issues dealing with students' learning motivation and their learning styles (Munawaroh et al., 2022; Sudarman & Ardian, 2021; Balakrishnan et al., 2019; Mahamod & Somasundram, 2017). Due to this, the concept of 'teach for test' does not work anymore in which the students' learning should not learn because of aiming to get good results; but it is crucial to ensure that students learn for the sake of learning (Yashinsky, 2023).

Understanding the learning styles of students is essential for designing effective instructional methods and supporting learners with diverse needs (Idris et al., 2023). Effective learning happens when the learners are being active and highly motivated to obtain the knowledge (Ferlazzo, 2021; Hennessey, 2019). However, in some of the schools, the teachers are still using the traditional ways of teaching which causes the students to be bored in class (Keiler, 2018). This is because the teachers lack of skills in developing or creating new learning material or methods (Balakrishnan et al., 2019). The use of textbooks is no longer attractive for the students to learn;

therefore, the teachers or educators should provide different ways of learning which promotes interactive, active engaging lessons (Hartikainen et al., 2019; Freeman et al., 2014).

In addition, the teachers who rush for the syllabus also make the students lose their motivation to learn because they are unable to catch up on the notes, or not having enough time to understand the whole concept (The Star, 2023; The Straits Times, 2021; Mahamod & Somasundram, 2017). This makes the students reduce their interest in learning science. According to Keiler (2018), teacher-centred lessons with 'talk and chalk' caused the students to be passive learners. Therefore, in this study, an educational tool which is a Science-integrated with Art learning module has been developed, named "ArtSci-S.P.D. Module". As this module promotes a student-centred, active learning approach – where the students are encouraged to learn by experiences on their own.

According to Lawrence, Lim and Haslinda (2019) as cited in Ling et al. (2024), the approach of teaching and learning in a lesson will gradually experiences changes and shifts in the future, because this action is to keep up with the pace of students' development in terms of academic or personal learning skills, which aiming to improve their knowledge and skills that necessary to adapt to 21st century era. Therefore, interdisciplinary is beneficial in helping with this issue.

The learning of science using/with art is a more integrated method of learning, which can enhance a more students-

centred and active learning which give positive impact on students' learning, allowing them to explore knowledge; at the same time, to develop the 21st century skills needed for the future (Ling et al, 2024). Students' involvement in the learning process is important when they are able to experience the learning by hands-on activity or Doing, the learning becomes meaningful (Dewey, 1988). Thus, the Art-Integration in Science learning which promotes hands-on experiences, helps in allowing the students to learn and understand more when doing the artworks.

Background of Study

The paper aims to discuss the validity and reliability of the ArtSci-S.P.D. Module obtained. The ArtSci-S.P.D. module, a learning module developed for this research on Year Five Human Circulatory System, a topic that is under the Malaysian National Year Five Primary Curriculum (KSSR) Science syllabus. It is a module that uses the idea of Art-Integration in Science learning. It promotes hands-on and learning-by-doing concepts. This module uses the Malay language medium because it is developed for Year Five students who study at Malaysian National Primary School or 'Sekolah Rendah Kebangsaan (SK)'. This module will then be used in the real study later for investigating the effectiveness and usability of the module. Thus, it is important to check its validity and reliability before the module is used in real study.

Objectives

In this study, the objectives of this study are as follows:

- (I) Determine the validity of the ArtSci-S.P.D. Module of Year 5 Human Circulatory system.
- (II) Determine the reliability of ArtSci-S.P.D. Module of Year 5 Human Circulatory system.

Materials and Methods

The design of the study is a quantitative method. The validity of the module is determined by the experts in the relevant field of expertise and the reliability of the module is determined by the sample students who are involved in a pilot study.

A good instrument can be established through the analysis of validity and reliability (Masuwai, Zulkifli & Hamzah, 2024). The ArtSci-S.P.D. Module is an instrument that will be used for measuring the aim of real research later. Therefore, it is vital to evaluate the module's validity and reliability to ensure it is relevant and suitable to be used in real study later (Sundram & Romli, 2023; Sürücü & Maslakçi, 2020; Taherdoost, 2016).

Validity of Module

Validity refers to whether the measuring instrument does what it is supposed to measure and performs as intended (Sudaryono et al., 2019; Creswell, 2012). According to Chua et al. (2020), the validity of a module refers to assessment on the module in terms of its accuracy of concepts and contents in the module. In this study, face validity and content validity are both tests used to evaluate the validity of the module.

Three panels who are experts in language and educational evaluation selected for assessing the face validity and seven experts for content validity panels based on their expertise in science or visual art education. The responses of each panel are collected using the questionnaire; Face Validation Form and Content Validation Form. Table 1 shows the panel list for the validation process of ArtSci-S.P.D. module.

Table 1. Panel list for face and content validity assessment on module

Expert	Field of expertise/Position	Working Years	Validation process
A	Malay language/ Lecturer	16	Face Validity
B	Malay language & Visual Art/ Primary school teacher	10	Face Validity Content Validity
C	Educational Measurement and Evaluation / Lecturer	17	Face Validity
D	Science(primary school)/ Senior teacher	16	Content Validity
E	Science(primary school)/ Teacher	26	Content Validity
F	Science(primary school)/ Teacher	15	Content Validity
G	Science(primary school)/ Teacher	7	Content Validity
H	Science(primary school)/ Teacher	18	Content Validity
I	Visual Art/ Senior teacher	21	Content Validity

The judgement of the validity test is based on the appropriateness, meaningfulness and ambiguity of each question to determine how accurately the questionnaire taps into the various aspects of the construct questions. For the face validation of the module, the responses are collected using "Agree" or "Disagree" scales, the data is then analysed by Fleiss' kappa method. Fleiss' kappa is a statistical method used to measure the inter-rater agreement or reliability of agreement between multiple raters (more than two raters) on a measured scale (Fleiss, 1971; Fleiss, Levin & Paik, 2003).

While, for the content validation, the agreements of experts are collected using a Four-points Likert scale: Strongly Disagree (1), Disagree (2), Agree (3) and Strongly Agree (4). There are 16-item asking about the experts' opinion on the content in the module including the instruction part, learning objectives, suitability of image, notes, exercise and visual art activity. The data is then analysed by Content Validity Index (CVI) as proposed by Polit, Beach and Owen (2007).

The content validity index is a measure of inter-rater agreement commonly used to calculate the level of agreement among raters (Moustafa, 2020). According to Lynn (1986), the minimum level of CVI between five and 10 validators is at ≥ 0.78 , that means if the CVI less than 0.78 needs to be revised. Table 2 shows the acceptable cut-off value of I-CVI and S-CVI/Ave for seven experts (Polit et al., 2007; Waltz et al., 2005).

Table 2. Acceptance of CVI value and its Interpretation

Acceptable value of CVI	Interpretation
Value of I-CVI	Excellent
At least 0.83 (should not less than 0.78)	
Value of S-CVI/Ave	Excellent
0.90	

Reliability of Module

The reliability of ArtSci-S.P.D. Module was assessed through a pilot study with 27 sample students. The data of pilot use of the module is collected based on the Pre-test and Post-test. The score of Pre-test and Post-test intended to check for the reliability of the module (May & Ahmad, 2018). The data is analysed using the test-retest reliability method to obtain the value of Pearson's correlation coefficient, r on a value between -1 and 1.

According to Cronk (2024) and Kennedy (2022), test-retest reliability refers to a test of 'stability' which provides an indication of stability measurement and consistency of an instrument over time. A measure is said to have high reliability if it produces similar results under consistent conditions (Oktavia et al., 2018). The analysis using Pearson's correlation indicates whether there is a linear relationship between the scores of pre-test and post test (May & Ahmad, 2018). This linear relationship can be a positive or negative relationship (Schober et al., 2018). The degree of Pearson's correlation can be interpreted as follows in Table 3 (Cronk, 2024).

Table 3. Indicator of Pearson's correlation coefficient

r value	Interpretation
$ r \geq 0.7$	High degree of relationship (Strong Correlation)
$0.3 \leq r < 0.7$	Moderate degree of relationship (Moderate Correlation)
$ r < 0.3$	Low degree of relationship (Weak Correlation)
0	No relationship or Correlation

The Pre-test was given to the samples at the one week before starting using the module to learn, then three weeks of usage of the module to learn. At the end of the period of study, the Post-test was given to the samples. This method involves administering the same test to the same group of participants at two different points in time, then comparing the results to determine the consistency of the module's performance. Overall, the reliability test of the module (pilot study) took around four weeks to complete.

Results and Discussion

Validity of ArtSci-S.P.D. Module

The module is being evaluated for the face validity and content validity. The validation is done by the selected experts. Table 4 shows the response from three experts in evaluating the Module's Face Validity and Table 5 shows the comments about the overall of the module in terms of accuracy and appropriation.

Based on the comments from experts, the researcher had made some modifications to the module in order to make sure that the module is appropriate to be used in actual study.

Table 6 shows the results of Fleiss' kappa. According to Fleiss et al. (2003), Fleiss' kappa is the extension of Cohen's kappa where the value of 0.75 and greater is considered excellent agreement between panels and $0.40 < k < 0.74$ is acceptable and indicated good strength of agreement.

The content validation process was done by seven experts. Table 7 presented the results of the content validity of the ArtSci-S.P.D. Module. Based on the table, the value of both CVI (I-CVI and S-CVI) indicates the module's content is valid.

Table 4. ArtSci-S.P.D. Module's Face Validity

Evaluation Item	Expert A	Expert B	Expert C
Appropriate and attractive format and layout	1	1	1
Appropriate and attractive colour used in the module	1	1	1
Suitable font size	1	1	1
Suitable font type	1	1	0
There are no spelling mistakes	0	0	0
Appropriateness of grammar	0	0	0
Use of simple language	1	1	1
Appropriate sentence structure	1	0	1
Relevant text arrangement	1	1	1
Appropriate and attractive visuals and pictures in the module	1	1	1

*Note: '0' indicates Disagree; '1' indicates Agree

Table 5. Panels' comments on Improvement of the ArtSci-S.P.D. Module

Expert	Comments
A	- Please refer to the spelling correction in the module as I written down - Sentences has a little problematic, recommended to rearrange
B	There are some spelling mistakes in the module, please refer.
C	- Some font size is quite small to read by the kids - There is quite a lot of different font type used in the module

Table 6. Results of Face Validity of ArtSci-S.P.D. Module

Fleiss kappa, k	Interpretation
0.659	Good

Based on results above, it shows a strong agreement among the seven panels on the content validity of module. As Polit et al. (2007), Waltz et al. (2005) and Lynn (1986) commented that the value of I-CVI should be at least 0.83; thus, the obtained I-CVI value at table above are considered pass the cut-off points. Next, the S-CVI for overall of the content validity of module also achieved a excellent level of agreement. Therefore, the ArtSci-S.P.D. Module has a good content validity.

Reliability of ArtSci-S.P.D. Module

For the reliability test of ArtSci-S.P.D. Module analysed by test-retest reliability using Pearson's correlation. According to Cronk (2024), Pearson's correlation coefficient can tell the how strong is level of relationship between the scores. By using the test-retest reliability method, if there is a relationship occurs, this is meaning that the module is showing 'stability' over time. Based on the results obtained, the Pearson's correlation coefficient is $r = 0.868$ where this value indicates it is strong positive correlated ($|r| \geq 0.7$) and significantly different from zero ($p < 0.001$). There is significant correlation between the test scores obtained for the Pre-test and Post-test. Thus, as the data indicate, the ArtSci-S.P.D. Module possess

Table 7. Results of Content Validity of ArtSci-S.P.D. Module

Items	Expert in agreement	I-CVI	Interpretation
Introduction	7	1	Excellent
Table of Contents	7	1	Excellent
Learning Objectives are clearly stated.	7	1	Excellent
Contents of each subtopic in the module are appropriate and relevant.	7	1	Excellent
Facts and knowledge that given able to fulfil the content and objectives of teaching topic.	7	1	Excellent
Learning activities that given able to measure the learning objectives.	7	1	Excellent
The extra notes that were added are appropriate for learning the topic of human circulatory system.	7	1	Excellent
The 'Fun-facts' and 'Do you know' are appropriate.	7	1	Excellent
Reinforcement activities [on pg 6, 9, 18, 22, 27] are appropriate.	7	1	Excellent
Reinforcement activities are able to measure the learning objectives.	7	1	Excellent
The ArtSci activities 1, 2, 3 and 4 are appropriate with the content of subtopics.	7	1	Excellent
Clear instructions for ArtSci activities 1, 2, 3 and 4.	6	0.86	Excellent
The ArtSci activities 1, 2, 3 and 4 are fun and interesting.	7	1	Excellent
All QR codes are functioning.	7	1	Excellent
All QR codes are suitable for the contents.	7	1	Excellent
Contents in the module are easy to understand.	7	1	Excellent
S-CVI/Ave		0.99	Excellent

adequate stability and significant reliability. Table 8 shows the results of Pearson's correlation coefficient between Pre- and Post-Test scores of pilot study – reliability of this module.

Table 8. Pearson Correlation (Test-Retest Reliability test)

	Pearson Correlation	Significance (2-tailed)
Pre-Test	r = 0.868	< 0.001
Post-Test		

Conclusions

The validity and reliability process are important steps to be taken to evaluate the instrument before the instrument being used in the actual research. In this study, validation on the face and content of the developed module, named ArtSci-S.P.D. Module has been assessed by selected experts. Based on the results obtained, the module shows a good, valid result on its validity test ($k = 0.66$; $CVI > 0.78$). Besides that, the module also measured the reliability of the module using the test-retest reliability with obtaining a high reliability value of $r = 0.87$ ($r \geq 0.70$). Thus, the ArtSci-S.P.D. Module is tested valid and reliable, accepted to be used in the actual study for measuring its effectiveness and usability.

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Визначення валідності та надійності застосування модуля з інтеграції мистецтва в науково-освітній процес (ArtSci-S.P.D.) щодо вивчення системи кровообігу людини на 5-му році навчання шкільної освіти

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 6 с., 8 табл., 34 джерел.

Мета дослідження. Мета дослідження полягала у визначенні валідності та надійності розробленого навчального модуля з інтеграції мистецтва в науково-освітній процес, що позначається як ArtSci-S.P.D. Впровадження модуля проведено задля підтвердження доцільності його застосування в подальших дослідженнях.

Матеріали та методи. В якості підходу до аналізу очевидної валідності використовувався показник каппа Флейса, тоді як для оцінки валідності змісту застосовувався індекс валідності змісту (ІВЗ), а для вимірювання надійності — метод тест-ретестової надійності. Розрахунок тест-ретестової надійності здійснено за допомогою коефіцієнта кореляції Пірсона.

Результати. Отримані дані свідчать про позитивну тенденцію щодо оцінки очевидної та змістової валідності (каппа Флейса, $k = 0,66$; ІВЗ $> 0,78$). Крім того, модуль має високий коефіцієнт надійності ($r = 0,87$).

Висновки. Таким чином, зазначений модуль вважається валідним і надійним інструментом з точки зору застосування в рамках актуального дослідження, що підкреслює його ефективність.

Ключові слова: інтеграція науки і мистецтва, навчальний модуль, валідність, надійність, тест-ретестова надійність, кореляція Пірсона.

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Characteristics of the Approximate-Optimal Training Indicators of Goalkeepers in Modern Football

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Abstract

Objectives. Is to systematize data on determining approximate and optimal indicators of training activities of goalkeepers in football at different stages of sports improvement in order to improve their training.

Material and methods. 14 athletes who are training at MFC "Metalurg" (Zaporizhzhya), playing the role – of goalkeeper: 3 athletes – MFC "Metalurg" (Zaporizhzhya), 3 athletes – MFC "Metalurg, U-19" (Zaporizhzhya), 2 athletes – MFC "Metalurg, U-17" (Zaporizhzhya), 2 athletes – MFC "Metalurg, U-16" (Zaporizhzhya), 2 athletes – MFC "Metalurg, U-15" (Zaporizhzhya), 2 athletes – MFC "Metalurg, U-14" (Zaporizhzhya). Age range: 14-24. Term of preparatory training period: 01.08.2024 – 24.11.2024.

Methods of research. Analysis and systematization of data from scientific literature and the resource of global information system "Internet"; pedagogical observations; analysis of video materials of training sessions and the competitive process, generalization of pedagogical experience and systematization of scientific data; pedagogical observations; analysis and evaluation of indicators of training and competitive activities of football players – goalkeepers; methods of mathematical statistics.

Results. Analysis of the competitive activity of qualified goalkeepers allows us to state that the average goalkeeper in modern football – a participant in the latest world and European championships, UEFA tournaments has the following anthropometric parameters: height – 195 ± 2 cm; weight – 90 ± 2 kg; weight-height index – 0.45 ± 0.01 c.u. The analysis of the data contained allows us to state the presence of certain relationships between the indicators of morphometry and the level of development of motor abilities of football players of various playing roles with the indicators of the effectiveness and efficiency of their competitive activities: goalkeepers show reduced correlations with endurance development; flank defender and midfielder have reduced indicators of the relationship between the effectiveness of competitive activity and morphometric indicators and manifestations of flexibility.

Conclusions. The results of experimental studies allow us to state that in the process of long-term sports training of football goalkeepers, the most significant psychological characteristics of the individual are: a high level of motivation to achieve the set goals, hard work, determination and psychological stability in the process of training sessions and competitive activities. In addition, the following indicators are critically important for the high-quality training of goalkeepers for professional football teams: morphometric parameters (height, limb length, weight, limb structure, muscle structure and ligament-articular apparatus), the level of development of leading motor abilities, manifestations of anticipatory reaction and subjective forecasting (anticipation of the flight of the ball, the moment and direction of the blow, the development of the game situation), physical fitness (general and special) and the pace of learning specific motor and technical-tactical actions of the goalkeeper.

Keywords: football, training indicators, characteristics, goalkeeper, sports preparation.

Introduction

Modern football is characterized by a high level of competition: the volume and intensity of loads in the process of training top-class athletes are almost exhausted or close to the

limits of the functional capabilities of the human body. In this situation, the issues of optimizing the educational, training and competitive activities of football players of different ages, playing roles and qualifications are especially relevant.

In these conditions, the process of long-term sports training and high-quality competitive activity of young football players is of particular importance in terms of optimizing

the preparation of a qualified reserve for professional football teams. In this area, one of the central places is occupied by the study, analysis and generalization of the characteristics of the educational, training and competitive activity of young goalkeepers in football from the point of view of optimizing the process of preparing a high-quality reserve for professional football teams. The undoubted importance of this problem is due to the practice of modern football – the increased level of competition between professional football teams dictates the need to study, analyze and generalize the process of long-term training of young goalkeepers in football and the development of practical recommendations for coaches, coaches-teachers of children's and youth sports schools and coaches-selectors.

An analysis of literary sources on this issue indicates a significant interest of Ukrainian and foreign scientists in its solution. The study (Doroshenko, Shalfeev, Vorobets et al., 2007) focuses on the characteristics of the leading components of the training and competitive activities of goalkeepers in football in the system of long-term sports training. Shamardin and Khorkavyy (2015) they focus on the rational organizational structure of the system of sports training for goalkeepers in football, which, in their opinion, will allow optimizing the system of long-term sports training in general. Lisenchuk, Leleka, Bogatyrev et al. (2021) note that the existing relationships between the technical, tactical and physical fitness of goalkeepers in football are of critical importance for the training system in the age range of 13-14 years.

Other researchers identify psychological characteristics, multisensory reactions of the body, and motivational factors of athletes as the leading component of the training process and competitive activity (Singchainara, Harnmak, & Butcharoen, 2022; Quinn, Hirst, & McGovern, 2023; Akbar, Karim, & Zakaria, 2024).

The problematic issues of preventing sports injuries and the most effective construction of the rehabilitation process for goalkeepers in football are highlighted in the studies of medical and rehabilitation specialists (Doroshenko, Malakhova, Chernenko et al., 2019; Muracki, 2020; Muracki, Klich, Kawczynski & Boudreau, 2021).

The research (Goncalves, Clemente, Barrera et al., 2021a; Goncalves, Clemente, Barrera et al., 2021b) includes technologies for taking in to account the specific features of the female body in the formation of a rational construction of the training process for goalkeepers in football with an emphasis on medical, biological and psychological and pedagogical components.

The methodological issues of training highly qualified goalkeepers in football are highlighted in studies with an emphasis on its compliance with more applied concepts, in particular the application of testing theory in football (Abe, Ambe, Okuda et al., 2022; Hrybovska, & Zanevskyy, 2024).

Modern technologies for optimal assessment of the effectiveness of goalkeepers' competitive activities in football are presented in research (Kubayi, 2020; Mikikis, Michailidis, Mandroukas et al., 2021; Szwarc, Chamera, Duda et al., 2023).

The works of scientists devoted to the study, justification and expert analysis of factors that influence the effectiveness of goalkeepers' competitive activities in standard situations (penalties), taking in to account the possibility of the

manifestation of a predictive reaction, which is inherent in top-class athletes, are of considerable interest to researchers (Monteiro, dos Santos, Blauberger et al., 2024; Zheng, van der Zijden, Janssen, van der Kamp, 2024).

The presented scientific material indicates a sufficiently high level of study of the mentioned issues, but the issues of determining the approximate and optimal indicators of the training activities of goalkeepers in football at different stages of sports improvement, which can be used as model characteristics, remain relevant and ultimately unresolved.

Hypothesis. Solving problematic issues regarding the determination of approximate and optimal indicators of goalkeepers' training activities in football at different stages of sports improvement, which can be used as model characteristics, will contribute to the improvement of their sports training.

The purpose of the work: to systematize data on determining approximate and optimal indicators of training activities of goalkeepers in football at different stages of sports improvement in order to improve their training.

Material and Methods

Participants

14 athletes who are training at MFC "Metalurg" (Zaporizhzhya), playing role – goalkeeper: 3 athletes – MFC "Metalurg" (Zaporizhzhya), 3 athletes – MFC "Metalurg, U-19" (Zaporizhzhya), 2 athletes – MFC "Metalurg, U-17" (Zaporizhzhya), 2 athletes – MFC "Metalurg, U-16" (Zaporizhzhya), 2 athletes – MFC "Metalurg, U-15" (Zaporizhzhya), 2 athletes – MFC "Metalurg, U-14" (Zaporizhzhya). Age range: 14-24. Term of preparatory training period: 01.08.2024 – 24.11.2024.

Methods of Research

Analysis and systematization of data from scientific literature and the resource of global information system "Internet"; pedagogical observations; analysis of video materials of training sessions and the competitive process, generalization of pedagogical experience and systematization of scientific data; pedagogical observations, analysis and evaluation of indicators of training and competitive activities of football players – goalkeepers; methods of mathematical statistics.

Organization of Research

Experimental research was carried out during the preparatory period and during the first round of football season 2024-2025:

- PFL (professional football league of Ukraine, 1 league, group "B") – 3 athletes;
- CYFL, U-19 (children's and youth football league of Ukraine, 1 league, 3 group) – 4 athletes;
- CYFL, U-14 – U-17 (Children's and Youth Football League of Ukraine, Elite League, 4 group) – 8 athletes.

Experimental research was carried out in accordance with the standards and criteria for experimental scientific research, as contained in medical research documents (Declaration of Helsinki).

Statistical Analysis

The obtained experimental materials were processed by the package of application programs "IBM SPSS Statistics" with the calculation of the following indicators: arithmetic mean (X); arithmetic mean error (S); % – percentage value.

Results

Analysis of competitive activity of qualified goalkeepers allows us to state that the average goalkeeper in modern football – a participant in the latest world and European championships, European cup tournaments has the following anthropometric parameters: height – 195 ± 2 cm; weight – 90 ± 2 kg; weight-height index – 0.45 ± 0.01 c.u. (conventional unit). Probably, these indicators of height, weight and weight-height index are approximately optimal for successful competitive activity of qualified goalkeepers in modern football.

In addition, the somatotype of highly qualified goalkeepers has distinct features: longer, relative to the body, upper and lower limbs, slightly enlarged hands. A number of features are observed in the postural activity of football players of this role – in the posture, shoulders are slightly forward, which has a beneficial effect on catching balls and performing various game techniques while falling (forward and to the sides). Elongated limbs are considered conservative features, and this is recorded in childhood or adolescence. The position of the shoulders, slightly pushed forward, can be both an element of the formation of natural posture (genetic factor), and the result of many years of educational, training and competitive activity (factor of adaptation to the effects of the external environment).

In addition, experts (theorists and practitioners) highlight several pronounced personal qualities that distinguish highly qualified goalkeepers in modern football.

Motivation: a high level of motivation, which is expressed in the further formation of purposefulness, allows goalkeepers in football to significantly realize their abilities in the process of competitive activity, to maximize their technical and tactical potential in the competitive process.

Focus on achieving the highest possible results is manifested in a conscientious attitude to the educational and training process and competitive activity, especially in the process of individual training.

Hard work. The maximum realization of sports potential is possible only under the condition of the highest possible physical and mental performance. Without this, even with talent, the presence of genetic prerequisites for the formation of outstanding motor abilities, it is almost impossible to achieve the integral indicators of highly qualified goalkeepers.

Determination. Defending the gate, the goalkeeper often enters into tough single combats with opponents. At the same time, manifestations of determination are associated with overcoming the fear of the possibility of injury and with aggressiveness in game actions, on the one hand, and with the development of the reaction of anticipation of the game situation, on the other hand. The use of elements of psycho-emotional impact is necessary to improve the neuropsychic state of the goalkeeper and football players of his team, to instill uncertainty in the actions of the players of the opposing team.

Psychological stability. The competitive activity of a goalkeeper is associated with high responsibility for the final result of the competitive process, which creates additional psychological pressure. Therefore, psychological stability is a dominant psychophysiological criterion that allows to a large extent to level out stress factors in difficult game situations, under pressure from fans and unfavorable climatic factors. It is quite difficult to achieve this psychological state, and it is even more difficult to maintain the required level in a long-term competitive process. Kaka's training and competitive practice shows that such personal qualities are predominantly possessed by football goalkeepers with sanguine and phlegmatic types of temperament – these personal qualities, to a large extent, determine the success of educational, training and competitive activities in the process of long-term preparation in football.

Based on pedagogical observations of the training and competitive process of football players of various playing roles, indicators of the level of influence of morphometric indicators of body structure and indicators of motor ability development on the effectiveness and efficiency of their competitive activities have been identified and systematized (table 1).

The analysis of the data contained in table 1 allows us to state the presence of certain relationships between the indicators of morphometry and the level of development of motor abilities of football players of various playing roles with the

Table 1. The level of influence of motor abilities and morpho-functional indicators on the effectiveness of competitive activity in football for players of different specializations**, % (n = 14)

Game specialization (role)	Morphometry and motor abilities						vestibular stability
	morphometry	strength	speed	endurance	coordination	flexibility	
	Level of influence						
goalkeeper	75-100	75-100	50-75	25-50	75-100	75-100	75-100
central* defender	50-75	75-100	75-100	50-75	50-75	50-75	75-100
flank* defender	50-75	50-75	75-100	75-100	50-75	25-50	50-75
central midfielder	50-75	75-100	50-75	50-75	50-75	50-75	50-75
flank* midfielder	25-50	50-75	75-100	75-100	50-75	25-50	50-75
central forward	75-100	75-100	75-100	50-75	75-100	50-75	75-100
flank* forward	25-50	50-75	75-100	75-100	50-75	25-50	50-75

Notes: ** – when using the tactical scheme 1-4-3-3; * – right or left; 75-100% – high; 50-75% – medium; 25-50% – low

Table 2. Prerequisites for achieving a high level of sportsmanship of goalkeepers in football, (n =14)

Prerequisites	Heredity coefficient, c.u.	Development opportunities, %
morphometry:	0.66	
• height and length of limbs	0.69	0-25%
• weight	0.51	50-75%
• structure of limbs	0.68	50-75%
• muscle structure	0.77	50-75%
flexibility	0.69-0.89	75-100%
speed	0.67	50-75%
strength and speed	0.71	50-75%
the pace of learning and improving goalkeeper techniques	0.59-0.79	25-50%
anticipation reaction:	0.78	75-100%
• trajectory of the ball flight	0.79	75-100%
• moment and direction of impact	0.74	50-75%
• development of game situations	0.81	75-100%
subjective forecasting	0.79	75-100%
motivation	0.73	50-75%
mental and physical performance	0.77	75-100%

Notes: 75-100% – high; 50-75% – medium; 25-50% – low

Table 3. Organizational and chronological structure of long-term training of a goalkeeper in football, n = 14

Period	Stage	The main tasks of sports training	Age range
Initial and preliminary basic training	Definitions of predisposition and inclination to play in goal, mastering the skills and technical and tactical techniques of playing as a goalkeeper	Improving overall motor fitness. Mastering football skills. Developing motor skills.	Up to 10-11 years
Specialized basic training and preparation for higher sports achievements	Teaching game techniques and technical and tactical actions in various game situations and improving them. Development of sportsmanship	Teaching the basic elements of goalkeeper technique and improving them. Comprehensive and targeted development of specific motor skills. Comprehensive development of tactical skills and abilities.	Up to 14-15 years
Maximum realization of individual potential of athletes and maintaining athletic fitness	Improving sports skills and stabilizing their level	Improving special performance. Adaptation of technical and tactical skills and abilities to the conditions of professional football. Integrated preparedness.	Up to 21 years and beyond

indicators of the effectiveness and efficiency of their competitive activities:

- goalkeepers show reduced correlations with endurance development;
- flank defender and flank midfielder have reduced indicators of the relationship between the effectiveness of competitive activity and morphometric indicators and manifestations of flexibility.

Table 2 shows the indicators that reflect the statistical relationships between the individual characteristics of athletes, characterizing the potential for successful educational, training and competitive activities of goalkeepers in football and the possibilities for their development in the process of long-term sports training.

Table 3 systematizes the data of pedagogical observations of football goalkeepers at various stages of long-term sports training.

Discussion

The presented experimental material contains certain positions of scientific novelty, which clarify the direction of training effects in the process of long-term sports training of football goalkeepers. It is also important to focus the attention of researchers (theoreticians and practitioners) on the relationship between certain indicators of the development of motor qualities and psycho-physiological characteristics (anticipation reactions).

These characteristics are critically important for successful training and competitive activities in football (according to data Kostiukevych, Lazarenko, Konnov et al., 2022; Let-hole, Kubayi, Toriola et al., 2024).

In addition, researchers consider the morphometric profile of football goalkeepers to be critically important for successful competitive activities. Although, individual excep-

tions to these rules are, most likely, individual exceptions, based on the specific selection of football players and the tactical scheme of the game (according to data Kaplanova, Sagat, Gonzalez et al., 2020; Primasoni, Syamsuryadin Wahyuti, Arjuna, Miftachurochmah, 2024). As an example, we can recall the legendary football goalkeeper of FC "Barcelona" (Spain) Víctor Valdes Arribas, who, with a relatively short height (183 cm), defended the colors of the Catalan club during 2002-2014 and won many national and international tournaments.

Individualization of training is also critically important for optimizing the athletic training of football goalkeepers and the success of their competitive activities (Tienza-Valverde, Hernandez-Beltrana, Espadab et al., 2023; Spielmann, Otte, & Schumacher, 2024). This allows us to clarify the correspondence of individual model characteristics to the averaged and systematized data that specialists use as model characteristics of football goalkeepers.

There is an alternative point of view, which, as a dominant one, puts forward a comprehensive focus of the training process on the development of various aspects of the preparedness of football goalkeepers – technical and tactical, physical, psychological, taking in to account the development of tactical skills (Ibrahim, de Boodeb, Kingmac, & van Dieën, 2022).

The above indicates the need for further modification of the system of long-term sports improvement of football goalkeepers based on the use of innovative technologies (including instrumental ones), new methods and techniques, taking in to account the choice of the most rational means (Otte, Millar, & Klatt, 2020).

Prospects for further research in this area are based on the need for a more detailed study of the accompanying factors that are related to the areas of extra-training and extra-competitive activities. We are talking about the accelerated rehabilitation of football goalkeepers after cases of sports injuries, determining the most accurate prognostic criteria for successful professional development of athletes of this category, improving motivation and social status, etc.

Conclusions

The results of experimental studies allow us to state that in the process of long-term sports training of football goalkeepers, the most significant psychological characteristics of the individual are: a high level of motivation to achieve the set goals, hard work, determination and psychological stability in the process of training sessions and competitive activities. In addition, the following indicators are critically important for the high-quality training of goalkeepers for professional football teams: morphometric parameters (height, limb length, weight, limb structure, muscle structure and ligament-articular apparatus), the level of development of leading motor abilities, manifestations of anticipatory reaction and subjective forecasting (anticipation of the flight of the ball, the moment and direction of the blow, the development of the game situation), physical fitness (general and special) and the pace of learning specific motor and technical-tactical actions of the goalkeeper.

Conflict of interest

The authors state no conflict of interest.

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Характеристика орієнтовано-оптимальних тренувальних показників воротарів у сучасному футболі

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 7 с., 3 таб., 27 джерел.

Мета роботи: систематизувати дані щодо визначення орієнтовно-оптимальних показників тренувальної діяльності воротарів у футболі на різних етапах спортивного вдосконалення з метою вдосконалення їх підготовки.

Матеріал і методи. 14 спортсменів, які тренуються в МФК «Металург» (Запоріжжя), ампула – воротар: 3 спортсмени – МФК «Металург» (Запоріжжя), 3 спортсмени – МФК «Металург, U-19» (Запоріжжя), 2 спортсмени – МФК «Металург, U-17» (Запоріжжя), 2 спортсмени – МФК «Металург, U-16» (м. Запоріжжя), 2 спортсмени – МФК «Металург, U-15» (м. Запоріжжя), 2 спортсмени – МФК «Металург, U-14» (м. Запоріжжя). Віковий діапазон: 14-24. Термін підготовчого періоду навчання: 01.08.2024 – 24.11.2024. Методи дослідження: Аналіз та систематизація даних наукової літератури та ресурсів глобальної інформаційної системи «Інтернет»; педагогічні спостереження; аналіз відеоматеріалів навчально-тренувальних занять та змагального процесу, узагальнення педагогічного досвіду та систематизація наукових даних; педагогічні спостереження, аналіз та оцінка показників навчально-тренувальної та змагальної діяльності футболістів – воротарів; методи математичної статистики.

Результати. Аналіз змагальної діяльності кваліфікованих воротарів дозволяє стверджувати, що середньостатистичний воротар сучасного футболу – учасник останніх чемпіонатів Європи і світу, турнірів UEFA має такі морфометричні параметри: зріст – 195 ± 2 см; вага – 90 ± 2 кг; масо-зростовий індекс – $0,45 \pm 0,01$ у.о. Аналіз наведених даних дозволяє констатувати наявність певних взаємозв'язків між показниками морфометрії та рівнем розвитку рухових здібностей футболістів різного ігрового ампула з показниками результативності та ефективності їх змагальної діяльності: воротарі мають знижені кореляції з розвитком витривалості; у флангових захисників і півзахисників – знижені показники зв'язку ефективності змагальної діяльності з морфометричними показниками і проявами гнучкості.

Висновок. Результати експериментальних досліджень дозволяють стверджувати, що в процесі багаторічної спортивної підготовки футбольних воротарів найбільш значущими психологічними характеристиками особистості є: високий рівень мотивації досягнення поставлених цілей, працьовитість, цілеспрямованість і психологічна активність. стійкість у процесі тренувальних занять і змагальної діяльності. Крім того, критично важливими для якісної підготовки воротарів для професійних футбольних команд є такі показники: морфометричні параметри (зріст, довжина кінцівки, вага, будова кінцівки, структура м'язів та зв'язково-суглобового апарату), рівень розвитку провідних рухових здібностей, прояви вищезгаданої реакції та суб'єктивного прогнозування (передбачення польоту м'яча, моменту та напрямку удару, розвитку ігрової ситуації), фіз. підготовленість (загальна і спеціальна) і темп навчання конкретним руховим і техніко-тактичним діям воротаря.

Ключові слова: футбол, тренувальні індикатори, характеристика, воротар, спортивна підготовка.

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Restoration of Lost Functions in Students after Blast Traumatic Brain Injuries in the Process of Inclusive Physical Education

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Background. It has been determined that the main task of higher education today is to solve the problem of providing students who have been injured as a result of war with opportunities along with higher education and rehabilitation conditions.

Objectives. The purpose of the article is to determine the effectiveness of the developed program of inclusive physical education on the restoration of dynamic balance functions in students after blast traumatic brain injury.

Materials and methods. The research combined theoretical (analysis, synthesis, generalization) and empirical methods (pedagogical experiment, testing). Testing was realized using the Dynamic Gait Index and the method of stabilization. The experiment, which was realized during the academic year in the academic course of physical education, involved 30 male students after explosive traumatic brain injury, provided there were no complications.

Results. The developed program of inclusive physical education after blast traumatic brain injury is presented. The content of the program is aimed at providing maximum opportunities for differentiation of the educational process and implementation of an individual approach in its implementation. The results of the test control of students of the studied sample before the beginning of classes testified to significant deviations in the state of the studied parameters. According to the evaluation of the obtained control data, the studied indicators did not reach the level of «average», which is a consequence of the influence of blast traumatic brain injury on the state of dynamic balance and gait parameters. The final testing showed a difference in the studied parameters in response to the implementation of the proposed innovations. A statistically significant improvement was observed in determining the progress and effectiveness of the studied parameters of gait and balance in the range of 10-19.6 %.

Conclusions. For the first time, we have implemented a study of students after blast traumatic brain injury, in which we directly controlled the violation of dynamic balance and gait in inclusive physical education. The results obtained are evidence that strategies and approaches will be effective, efficient and lead to the desired result in the case of improving practical methods to develop a reliable evidence base.

Keywords: inclusion, physical education, student, balance, gait, blast traumatic brain injury.

Introduction

As a result of the full-scale invasion of Russia and the ongoing aggression of the Russian Federation on the territory of Ukraine, the frequency of blast traumatic brain injuries (TBI) among the population has increased dramatically. Since the main causes of blast TBI, along with combat injuries, are injuries caused by rocket attacks and bombardments, civilians, accurate statistics for the period of war in Ukraine are currently unavailable.

Meanwhile, TBI is now recognized as the most common type of traumatic injury, a cause of morbidity and mortality

(Aida, Chau, & Dunn, 2018) and disability (25-30%) worldwide (Ponsford et al., 2024). According to the WHO, the number of TBIs increases by an average of 2% annually, and in Ukraine, due to active hostilities, the rate of 120 thousand cases per year has doubled (Dzyak et al., 2023), which is also a factor in the health crisis (Ling, & Ecklund, 2011).

Given the multidisciplinary nature of the problem (Dzyak et al., 2023), higher education is also at the epicenter of the identified issue, as people after blast TBI join the ranks of students every year. Therefore, the main task of higher education in the short term is to solve the problem of providing students with war-related injuries with opportunities for rehabilitation along with education (Blavt, & Gurtova, 2024).



The issue is particularly relevant due to the high proportion of blast TBI among students, which, in the absence of rehabilitation measures, leads to serious functional impairment (Roby et al., 2024). This problem is also gaining relevance from an economic point of view, as students after blast TBI are people of working age who may eventually acquire the status of “person with a disability” (Misyura, 2023).

Analysis of recent research and publications. The literature indicates that despite the fact that mild TBI (mTBI) can lead to debilitating symptoms (Ganti et al., 2019), the damage can be hidden, and the body’s compensatory functions ensure vital activity, the need for rehabilitation measures is recognized by scientific research (Fulk et al., 2024; Blavt et al., 2024; Denby et al., 2020).

TBI occurs when external physical forces impact the head sufficiently to cause brain damage (Rauchman et al., 2023). It has been shown (Tramontano et al., 2020; Vander Vegt et al., 2023; Pérez-Rodríguez et al., 2021), that mTBI can cause long-term central nervous system disorders, loss of coordination, and other serious complications. In particular, studies (Klima et al., 2019; Hoffer, & Balaban, 2018) indicate that TBI injuries result in both cognitive and neuromuscular deficits. In particular, deterioration of vestibular coordination and gait (Dever et al., 2022) is recognized as one of the main consequences of blast TBI and a common impairment in individuals with post-traumatic brain injury (Harris et al., 2023).

Therefore, balance deficits have been identified as a factor limiting productive participation in social life (Alashram et al., 2020; Kiliç, Çelikyurt, & Algun, 2023) and education (Blavt, & Gurtova, 2023). Balance impairment is studied in terms of the need for rehabilitation interventions to correct gait (Marchetti, & Whitney, 2006), or a combination of gait and balance interventions in TBI rehabilitation (Bland et al., 2011; Rauchman et al., 2023) to improve quality of life (Joyce et al., 2022; Roby et al., 2024). It has been studied (Aligene, & Lin, 2013) that vestibular rehabilitation therapy prevents the progression of neurological complications of TBI and prevents the development of severe complications in the future.

In higher education institutions, physical rehabilitation is implemented in the process of an academic course of inclusive physical education (PE) (Blavt et al., 2023). Inclusion in education, which is the elimination of isolation in this process, is the subject of a wide range of research (Holland et al., 2023; Graham, 2023; Lieberman, Houston-Wilson, & Grenier, 2024). Instead, it is argued that PE has significant opportunities in the process of restoring the state of damaged functions of students with disabilities (Barber et al., 2024).

Meanwhile, despite the critical importance of inclusive PE in counteracting modern challenges to the impact on students’ psychophysical state, this issue is rather narrowly considered in the national scientific discourse. Even though in recent decades, the latest approaches aimed at avoiding or minimizing complications have been introduced into the practice of physical rehabilitation, the issue of rehabilitation of students after blast TBI is practically not discussed in the national scientific literature, especially given the impact of current military events in Ukraine.

Therefore, recovery after blast TBI as a prolonged process (Tefertiller et al., 2019) is of great practical importance, as it allows us to determine the validity of the rehabilitation approaches used as components of a comprehensive recovery

process that can prevent the progressive course of the injury (Fulk et al., 2024; Ganti et al., 2019).

Therefore, the restoration of lost body functions as a result of blast TBI in students in the process of inclusive PE deserves special attention and careful study to make the necessary adjustments to this process, taking into account the results of empirical studies, which currently remain limited. Ultimately, the findings will contribute to improved curricula and, consequently, to the effectiveness of the process of restoring lost functions due to war trauma in students with disabilities. Here we note the almost complete lack of research and recommendations on the modification of inclusive PE as a means of restoring the functions of the lost as a result of after blast TBI, especially taking into account the impact of modern military events in Ukraine.

Ensuring the recovery of body functions lost as a result of military injuries of the limbs in students with disabilities deserves special attention and careful research to make the necessary corrections in this process, taking into account the results of empirical studies. As a result, the obtained results will contribute to the improvement of educational programs, and, therefore, to the effectiveness of the process of restoration of lost functions due to war injuries in students with disabilities.

Ensuring the recovery of body functions lost as a result of military injuries of students deserves special attention and careful research to make the necessary corrections in this process, taking into account the results of empirical studies. As a result, the obtained results will contribute to the improvement of educational programs, and, therefore, to the effectiveness of the process of restoration of lost functions due to war injuries in students.

The purpose of the article to determine the effectiveness of the developed program of inclusive PE on the restoration of dynamic balance functions in students after blast traumatic brain injury blast TBI.

Material and Methods

Study Participants

30 students after blast TBI in the 1st year of study from Lviv Polytechnic National University, Drohobych Ivan Franko State Pedagogical University, H. Shevchenko National University “Chernihiv Colehium” and Taras Shevchenko Regional Humanitarian-Pedagogical Academy of Kremenets were involved in the experimental study.

The representativeness of the sample of participants was ensured by selecting students after a blast TBI sustained as a result of war. The possibility of involving students in the trial was certified by a medical professional who made a decision based on an assessment of the criteria for inclusion or ineligibility. Namely, control of their health status, absence of complications and contraindications.

The experiment was conducted exclusively with the anonymous written consent of the students. Students who agreed to participate in the study were given the right to withdraw from it at any time during the study, weighing the benefits and risks for themselves.

The study was planned and carried out following the principles of bioethics set forth by the World Medical As-

sociation (WMA–2013) in the Helsinki Declaration “Ethical Principles of Medical Research Involving Humans” and UNESCO in the “General Declaration on Bioethics and Human Rights”.

Design of the Study

The guiding principle in the choice of research methods, which is one of the key stages in the process of scientific research, was their reliability, which ensured the receipt of empirical data obtained by testing the hypothesis (Ivashchenko, 2020). For a more complete understanding of the problem, theoretical (analysis, synthesis, generalization) and empirical (pedagogical experiment) methods were used in combination. The systematization of scientific research was used to collect, analyze, and interpret data.

The pedagogical experiment included control tests. Tests designed to control balance usually consist of static and dynamic tasks (Gawronska et al, 2023). The choice of the test program was based on limited resources, including time, the need for a comprehensive assessment, and certain advantages, such as ease of implementation and interpretation. Therefore, the Dynamic Gait Index (DGI) (Physiopedia) was used to evaluate our study based on the detection of balance dysfunction and gait measurement in people with balance and vestibular disorders. Its scoring system provides clear insights into a patient's functional abilities.

The DGI procedure involves performing the functional walking tests are performed by the subject and scored out of three according to the lowest applicable category (Physiopedia). DGI it evaluates not only the usual steady-state walking, but also walking during more challenging tasks (Shirley Ryan AbilityLab).

Our study used the following items: stepping over and around obstacles, changing speeds, gait and pivot turn and stair ascent and descent, walking speed. Average walking speed = total distance travelled (m)/average time (s). It generally takes about 15 minutes to complete the 8 tests in the DGI (Physiopedia). A stopwatch was used as a time measurement tool.

Each item is scored on a scale of 0 to 3 with higher numbers indicating better performance of the specified task. Additionally, each item has specific criteria that must be met to be granted a specific score number. The test has a total score out of 24 (Marchetti & Whitney, 2006).

The method of stabilometry was implemented by the «Stabilan 01-2» stabilizer. It was used to establish the state of balance and maintain the center of gravity of the body. Each student in the study sample performed three attempts. The arithmetic mean of the three trials was used in the analysis. On the stable platform of the stabilograph, the subjects arbitrarily maintained an upright body position.

The level of balance development was determined by the coefficient of balance development (CBD, %), which is the minimum rate of change of the center of mass (CM), reflecting the degree of stabilokinetic resistance of the body to mass movement in the sagittal and frontal planes.

Research Organization

The comparative pedagogical experiment was conducted according to the plan over two academic semesters. The plan

contains information about each student in the study sample, a lesson plan, and a schedule for conducting control tests. The use of modern data archiving technologies ensured the protection of personal data and the safety of the students in the study sample.

Before the study, students were informed about its content, and the criteria for evaluating test results were clearly defined and agreed upon. The first stage of testing was conducted before the start of classes, and the second – at the end of the second semester. The criterion for the effectiveness of the study was the dynamics of the parameters under investigation. The evaluation was implemented taking into account the recommendations (Middleton, Fritz, & Lusardi, 2015).

Statistical Analysis

Statistical analysis was used as a tool for analysis, data systematization and automated reporting, which was implemented using the SPSS Version 24.0 mathematical calculation package (IBM Corporation). Statistical information is expressed in descriptive statistics. The arithmetic mean ($\bar{X}$) $\pm$ standard deviation (S) for each of the measurements was used as a generalizing characteristic. The median (Me) as an indicator of the central tendency. To assess differences, the difference between the measurements before and after was determined, and the Student's t-test was calculated. Differences were considered significant at $p < 0.05-0.001$.

Results

It has been determined (O'Sullivan, Schmitz, & Fulk, 2019) that physical rehabilitation is an important stage of recovery that results in the return of physical fitness lost due to injury. In the context of our research, recreational walking is recognized as an important component of rehabilitation for a wide range of diseases (Rapp et al, 2015), including blast TBI. The connection between gait speed and strength, mobility of nervous processes, hand function, daily activities, and maintenance of dynamic stability has been recognized (Schniepp, Möhwald, & Wuehr, 2017). At the same time, the potential of gait as a tool for reliable clinical assessment of the functional status of vestibular disorders has been investigated (Schmid et al, 2007), and balance control is a widely used tool in the management of BI (McKee et al, 2024).

Therefore, our empirical study is based on the fact that gait rehabilitation is part of the rehabilitation program for people with BI (Moseley et al, 2004) and is widely used to monitor the recovery of damaged functions (Van Loo et al, 2004; Middleton, Fritz & Lusardi, 2015).

The experiment involved the implementation of a rehabilitation program for the damaged functions of the students' bodies after blast TBI. The rehabilitation program was considered by us as a necessary basis for the formation and transformation of existing practices of inclusive PE. The expedient clear use of best practices from many sources ensured the effectiveness of the program. Its characteristic feature is the synthesis of diverse influences that complement and reinforce each other and are generally aimed at achieving its main goal - improving vestibular coordination and balance development.

Based on the position of a multidisciplinary approach and the implementation of continuous monitoring, the pro-

Table 1. Results of test control

Variables		Test tasks and measurement results										
		at the beginning of the experiment					after of the experiment					
		X	S	As	Me	V	X	S	As	Me	V	effect %
Gait level surface 10 м (s)		9.11	0.19	0.44	8.89	27.7	8.17	0.37	0.35	8.09	29.1	18.2
Around obstacle		1.95	0.26	0.03	1.88	31,5	2.35	0.33	0.07	2.28	28.3	16.2
Velocity (м/с)		1.09	0.16	0.02	0.97	26.7	1.22	0.11	0.02	1.18	26.7	15.9
Over obstacle		1.78	0.33	0.07	1.81	29.7	2.03	0.27	0.04	1.95	30.2	13.6
Stairs Gait		1.33	0.27	0,12	1.29	33.2	1.67	0.21	0.06	1.62	27.2	17.1
Change in gait speed		1.45	0.61	0.03	1.38	20.8	1.63	0,54	0.03	1.57	30.2	13.4
Number of steps		22.3	0.66	0.12	21.97	28.0	19.1	0.62	0.02	18.79	32.3	14.6
Step time (s)		0.22	0.14	0.06	0.19	31.2	0.19	0.11	0.04	0.17	27.4	15.7
Gait and pivot turn		18.3	2.33	0.21	18.08	25.2	15.88	2.05	0.11	15.67	28.1	14.6
Total score		14.2	1.23	0.07	13.51	25.6	16.76	1.51	0.42	15.52	25.7	19.6
CM in the frontal plane (mm)	open eyes	3.41	0.37	0.07	3.36	26.9	3.11	0.29	0.08	3.07	28.4	11.8
	closed eyes	3.98	0.33	0.09	3.95	28.1	3.59	0.52	0.48	3.56	30.2	14.7
CM in the sagittal plane (mm)	open eyes	3.04	0.39	0.08	3.16	29.2	2.65	0.24	0.12	2.68	24.9	14.1
	closed eyes	4.02	0.21	0.15	3.98	27.4	3.38	0.43	0.06	3.45	25.4	18.2
Area of an ellipse, (mm²)	open eyes	95.1	3.31	0.23	93.92	26.2	86.05	3.01	0.21	85.88	29.1	11.2
	closed eyes	175.0	3.99	0.32	174.2	28.6	155.3	4.01	0.35	154.3	31.3	12.3
CBD, %,	open eyes	61.0	5.1	0.45	58.2	30.1	68.2	3.9	0.31	66.1	28.3	12.2
	closed eyes	49.7	3.99	0.28	46.9	29.3	57.3	5.2	0.22	56.3	30.3	15.7

*The differences in the results at the beginning and after of the experiment are significant ($p < 0.05 - 0.001$)

gram provides for the correction of its implementation plan to use special exercises to eliminate vestibular dysfunction, focused on individual symptoms (Sawyer et al, 2016).

The program is distinguished by the developed sets of exercises for self-performance, which were selected based on recommendations for rehabilitation effects on the state of vestibular coordination (Brown et al, 2006) and control of this process (MacKinnon, 2018). The developed program of vestibular rehabilitation is aimed at eliminating the problem with balance by stimulating the organs of vestibular coordination and activating the plasticity of the vestibular system of students after blast TBI.

It is important that during the application of the program when evaluating the test results, we tried to find out which walking parameters showed an impact on the state of the students' vestibular system. The choice of evaluation criteria was guided by the fact that the time index of gait speed is a reliable indicator of control of the rehabilitation process in the case of SCI (Hirsch et al, 2004), and is also used as a predictor of reducing the symptoms of balance disorders to obtain potentially significant indicators of clinical benefit (Schmid et al, 2007). Adjustments to the program content were made based on the results of the initial control to maximize the benefits of the tools used.

The results of testing (Tab. 1) the students of the study sample before the start of classes showed significant deviations in the state of the studied parameters. According to the evaluation of the control data, the studied indicators did not reach the «average» level. Therefore, the data obtained indicate the impact of blast TBI on the state of dynamic balance and gait parameters. At the end of the experiment, the data

obtained, despite a significant improvement (+19.6 %), have not yet reached safe values.

In the second stage of control, the students of the study sample demonstrated an improvement in the parameters of balance and gait with obstacles and in difficult conditions. The test results showed a difference in the studied parameters in response to the implementation of the proposed innovations. Statistically significant improvement was observed in determining progress and efficiency A significant improvement in the speed of movement to reach the endpoint was recorded both in walking in a straight line and in difficult conditions.

Even though the descriptive statistical analysis of the stabilometry parameters did not show a complete restoration to normal or average values of the studied parameters after the experiment, it showed a relative stabilization of the upright posture, the destabilization of which in the sagittal and vertical planes was observed at the initial testing. The area of the ellipse, which is considered an indicator of balance control deficit, also showed pathological abnormalities at the beginning of the training, which is typical for people with TBI. A significant role of visual control in the testing process was observed, which is recognized as an important factor in the regulation of balance.

Discussion

Following modern narratives, higher education should be inclusive for all students, including students from vulnerable categories. In implementing the empirical study, we were guided by the fact that inclusive education in the context of

physical education involves the creation of programs that take into account different levels of ability and needs of each participant in the educational process (Telius et al., 2024).

Our study expands the scientific evidence on the need for specialized PE programs (Blavt, & Herasymenko, 2024; Blavt, & Gurtova, 2024), the implementation of which ensures the restoration of damaged body functions of students after blast TBI (Pérez-Rodríguez et al, 2021).

It has been confirmed (Schmid et al, 2007; Hao et al, 2024; Thorman et al., 2022), that an increase in gait speed is an indicator of improvement in the functional state of the body and overall quality of life (Tasseel-Ponche et al, 2023; Kiliç, Çelikyurt, & Alguna, 2023). Accordingly, data (Howell, Osternig, & Chou, 2015; Jain et al, 2023) on the impact of VE on balance and gait have been proven (Howell, Osternig, & Chou, 2015; Jain et al, 2023).

The information (Girardi, & Konrad, 1998; Tefertiller et al, 2019; Vander Vegt et al, 2022) on the feasibility of using vestibular rehabilitation tools, which is recognized (Thorman et al, 2022; Badke et al, 2004; Kiliç, Çelikyurt, & Alguna, 2023) as a highly effective method of eliminating functional disorders of the vestibular system and balance system, has been expanded. Our study is consistent with the information (Al-salaheen et al, 2010; Valovich McLeod, & Hale, 2015; Aligene & Lin, 2013) that vestibular rehabilitation provides improvement in gait and balance functions after BI.

The present study was the first to use DGI to monitor the dynamic balance of students after blast TBI, implemented in the framework of inclusive physical education. The obtained results expand the information of previous studies on the feasibility of using the control of gait and balance parameters in the rehabilitation process after blast TBI (Bland, Zampieri, & Damiano, 2011; Alashram et al, 2020; Joyce et al, 2022). And information about the possibility of correcting lost functions after TBI among university students (Smetana et al, 2024), and the need to take into account additional complexities in blast TBI.

We support the scientific approaches (Dever et al, 2022; Fino et al, 2018) regarding the need for further research to create a gait assessment procedure to fully determine gait disorders after TBI.

Conclusions

The high proportion of people with blast TBI during the war in Ukraine has become a significant problem among both military and civilians who become students of higher education institutions every year. The restoration of lost body functions due to blast TBI in students within an educational institution is realized in the process of inclusive PE.

The need for a comprehensive study of the issue of inclusion in physical education in higher education is due to the contradictions between the need for a large-scale restructuring of the national system, modernization of its components, development, and implementation of practical performance of the educational process of students who received blast TBI as a result of war and the lack of such experience in terms of inclusion in line with the challenges of the time.

The developed program of inclusive PE after blast TBI is presented. The content of the program is aimed at providing maximum opportunities for differentiation of the educational process and implementation of an individual approach in

its implementation. The results of the test control showed the effectiveness of the implemented innovations in the range of 10-19.5 %. A significant improvement in the studied parameters of balance and gait was found. The conducted research on the final assessment of DGI and the coefficient of balance development allows us to state the effectiveness of the implemented program of physical rehabilitation of students after blast TBI in the process of inclusive PE.

For the first time, we have implemented a study of students after blast TBI, in which we directly controlled the violation of dynamic balance and gait in inclusive PE. The results obtained are evidence that strategies and approaches will be effective, efficient and lead to the desired result in the case of improving practical methods to develop a reliable evidence base. The latter should be the basis for the formation of an appropriate practical basis for the implementation of inclusive physical education, the development of rehabilitation tools. Meanwhile, there is an obvious need for deeper, large-scale studies of blast TBI among students, as the choice of rehabilitation methods remains an open question.

Conflicts of Interest

No conflicts of interest exist.

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Відновлення втрачених функцій у здобувачів вищої освіти після вибухової черепно-мозкової травми в процесі інклюзивного фізичного виховання

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 8 с., 1 табл., 63 джерела.

Визначено, що нині основними завданнями вищої освіти в є розв'язання проблеми надання студентам, які отримали травми внаслідок війни можливостей поряд із здобуттям вищої освіти, умов реабілітації.

Мета статті – виявити ефективність впливу розробленої програми інклюзивного фізичного виховання на відновлення функцій динамічної рівноваги у здобувачів вищої освіти після вибухової черепно-мозкової травми.

Матеріали та методи. У дослідженні комбіновано застосовані теоретичні (аналіз, синтез, узагальнення) й емпіричні методи (педагогічний експеримент, тестування). Тестування реалізовано з використанням вправи «Індекс динамічної ходи» та методу стабілографії. До експерименту, який реалізовано протягом навчального року у академічному курсі фізичного виховання, залучено 30 здобувачів вищої освіти чоловічої статі після вибухової черепно-мозкової травми, за умови відсутності ускладнень.

Результати. Представлено розроблену програму інклюзивному фізичному вихованні після вибухової черепно-мозкової травми. Зміст програми скерований на забезпечення максимальних можливостей диференціації освітнього процесу та здійснення індивідуального підходу у його реалізації. Підсумками тестового контролю здобувачів вищої освіти досліджуваної вибірки до початку занять засвідчено про значних відхилень у стані досліджуваних параметрів. Згідно оцінюванню отриманих даних контролю, досліджувані показники не досягали рівня «середній», що є наслідком впливу вибухової черепно-мозкової травми на стан динамічної рівноваги та параметри ходи. Прикінцеве тестування засвідчило різницю досліджуваних параметрів у відповідь на впровадження запропонованих новацій. Статистично значуще покращення спостерігалось у визначення прогресу та ефективності досліджуваних параметрів ходи та рівноваги у межах 10-19.6 %.

Висновки. Нами вперше реалізовано дослідження щодо здобувачів вищої освіти після вибухової черепно-мозкової травми, у якому безпосередньо контролювали порушення динамічної рівноваги та ходи у інклюзивному фізичному вихованні. Отримані результати є свідченням того, що стратегії та підходи будуть ефективними, результативними та такими, що призводять до бажаного результату у разі вдосконалення практичних методик задля розробки надійної доказової бази.

Ключові слова: інклюзія, фізичне виховання, здобувач вищої освіти, рівновага, хода, вибухова черепно-мозкова травма.

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Understanding the Effects of Selected Backpack Loads Carried for Certain Durations on Peak Forces of Walking Gait in School-Going Boys

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Abstract

Background. Backpacks are commonly used by students to carry their school items. However, increasing backpack loads can lead to negative effects on health and posture, particularly through changes in gait dynamics. Peak forces are a critical variable in understanding gait mechanics, which is significantly impacted by carrying loads. Therefore, it is crucial to investigate the changes in peak forces with varying (increasing) backpack loads and the durations of carrying.

Objectives. The study aimed to examine the effect of various backpack loads, carried for different durations, on the forces at first and second peaks of the left and right foot during a walking gait cycle in school-going boys.

Materials and methods. The subjects ($n = 85$) between the age of 10 to 12 years, were randomly selected from Delhi NCR. The force at first and second peaks was measured using a ZebrisInc pressure platform supported by Win FDM-S software (Germany). Five backpack load conditions were analysed, namely, B1 = backpack load of 0 % of body weight (no additional weight in the backpack); B2 = backpack load of 8% of body weight; B3 = backpack load of 12 % of body weight; B4 = backpack load of 16 % of body weight; and B5 = backpack load of 20 % of body weight, at five following recording time, T1 = recording at zero minute of walking; T2 = recording at fifth minute of walking; T3 = recording at tenth minute of walking; T4 = recording at fifteenth minute of walking; T5 = recording at twentieth minute of walking. Statistical analyses included an assessment of the mean, standard deviation, coefficient of variation, and t-ratio. The significance level for the t-test was 0.05.

Results. The results indicated that increasing backpack loads led to higher peak forces at both the first and second peaks of the gait cycle. The right foot exhibited elevated forces at the first peak, while the left foot showed dominance at the second peak. Furthermore, prolonged load carriage was also found to increase peak forces. A paired sample t-test revealed significant differences between the first and second peaks, with a mean difference of -14.402 N ($p = 0.002$) for the first peak and 4.860 N ($p = 0.001$) for the second peak.

Conclusion. The study concluded that higher backpack loads significantly increased the mean of peak forces in walking gait, which may result in postural imbalances and gait asymmetry. These findings suggest a need for regulating backpack loads to prevent potential musculoskeletal issues in children.

Keywords: backpack, first peak, force, gait cycle, load carriage, second peak, walking gait.

Introduction

Backpacks are the most common means for school students to carry their belongings, as they are positioned close to the body's center of gravity, providing stability during movement (Pascos et al., 1997; Sheir-Neiss et al., 2003). While carrying a backpack may reduce biomechanical demands due to this optimal positioning, an increase in load significantly raises the energy expenditure required for transport (Castro

et al., 2013; Pau et al., 2015). However, the drawback of using backpacks is that excessive loads can have harmful effects on the body (Knapik et al., 1996; Knapik et al., 2004). Studies have shown that carrying heavy backpacks over extended periods can lead to a range of negative consequences, including altered gait pattern, shoulder pain, fatigue, redness, swelling, back pain, and foot blisters. Moreover, it increases the risk of musculoskeletal injuries such as kyphosis, lordosis, and shoulder drop, among others (Macias et al., 2008; Son, 2013; Song et al., 2014; Castro et al., 2015; Perrone et al., 2018; Sokhi et al., 2022).

In a normal gait cycle, the ground reaction force should equal the individual's body weight (Drerup et al., 2008). However, abnormal gait patterns, such as those induced by carrying heavy loads, can lead to improper distribution of forces and pressure on the feet (Kellis, 2001; Rai & Aggarwal, 2006). Several studies have reported changes in ground reaction force, plantar pressure (Kasović et al., 2018), and gait patterns during load-bearing walking (Ahmad & Barbosa, 2019). It has been observed that students exhibit slower cadence and reduced walking speed when carrying heavy backpacks, with force and pressure time integrals increasing proportionally with the load (Ahmad & Barbosa, 2019). Additionally, when school children carry backpacks exceeding 10 percent –15 percent of their body weight, they experience decreased lung volumes and exhibit compensatory postural and gait changes, such as forward leaning of the upper body and head lowering (Lai & Jones, 2001; Mosaad & Abdel-Aziem, 2015; Vieira & Ribeiro, 2015; Chen et al., 2018). In a gait cycle there are two peaks, namely, first peak and second peak (refer Figure 1).

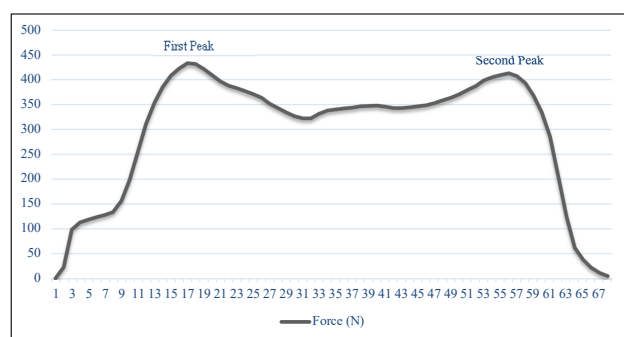


Fig. 1. Phases of first and second peaks in a gait cycle

The first peak occurs during the loading response phase, just after the heel touches the ground. This peak shows the body's ability to absorb impact as the weight shifts to the leading leg. The force at this point is mainly passive, helping the body stabilize under the load, and it can increase with extra weight, like carrying a backpack (Hong & Bartlett, 2008; Richards et al., 2013).

The second peak happens during the propulsion phase, right before toe-off. This is an active force where the plantar flexor muscles push the body forward (Neptune & Sasaki, 2005). Although the second peak is often smaller than the first, it is essential for moving efficiently and keeping momentum (Neptune & Sasaki, 2005; Richards et al., 2013). Any imbalance between these forces, especially from carrying heavy loads, can affect walking patterns and raise the risk of injury (Perry & Burnfield, 2010; Ahmad & Barbosa, 2019).

There are several determinants of plantar pressure, with peak force being a critical variable (Menz & Morris, 2006). Despite the increasing literature, there is limited research focusing on the specific impact of different backpack loads carried over varying durations on forces at different peak phases of the gait cycle. The current study aims to address this gap by examining the effects of varying (increasing) backpack loads carried over selected durations on force at first peak and second peak during walking in school going boys. The findings will contribute to a better understanding of how

backpack loads influence foot biomechanics and offer insights for reducing the negative effects of heavy backpacks in school children.

Material and Methods

Study Design

The research aimed to observe and analyse the forces at different (first and second) peaks during backpack load carriage at different load percentage of body weight in a gait cycle. The study utilized a repeated measures experimental design, in which all participants were exposed to five different levels of backpack loads, namely, backpack load of 0% (no additional weight in backpack) of the bodyweight, backpack load of 8% of the bodyweight, backpack load of 12% of the bodyweight, backpack load of 16% of the bodyweight, and backpack load of 20% of the bodyweight. Data collection occurred at five specific time intervals during backpack carriage, that is, at the starting of the test (zero minute), and then at the fifth minute, tenth minute, fifteenth minute, and twentieth minute of walking. This 5x5 within-group design allowed for repeated measures across both the varying loads and the different durations.

Subjects

Eighty-five male school-going students from Delhi NCR, aged 10 to 12 years, were randomly selected for this study. Ethical approval was granted by the Board of Research Studies at the University of Delhi (Ref No: DPE/2023/2345). The study adhered to strict ethical guidelines, ensuring voluntary participation, confidentiality, and the right to withdraw at any time. Participants who did not meet the age or health criteria, or who withdrew during the study, were excluded.

Instruments

The portable pressure measurement platform from ZebrisInc; Germany (40x30 cm), supported with Win FDM-S software (Germany) was used for collecting data over five trails for each foot from each subject. A weight machine was also used to measure the bodyweight of the selected subjects and to measure the backpack load.

Selection of the Variables

The study involved the selection of several key variables, categorized into experimental and observational variables. The experimental variables, also known as independent variables, included the backpack load and the duration of carrying the load. The backpack load varied across five levels: 0% of the subject's body weight (representing no additional weight in the backpack), 8%, 12%, 16%, and 20% of the subject's body weight. Additionally, the duration of carrying the backpack load was recorded at five different time points during walking. These time points were at the beginning of the walking gait (zero minute), the fifth minute, the tenth minute, the fifteenth minute, and the twentieth minute of the walking gait.

The observational variables, referred to as dependent variables, included several measures related to the forces exerted on the feet during walking. These included the force at

the first peak of the left foot, the force at the second peak of the left foot, the force at the first peak of the right foot, and the force at the second peak of the right foot. In addition, the study recorded the mean force at the first peak of both the left and right foot, and similarly, the mean force at the second peak for both feet. Moreover, the study calculated the mean of the forces at the first and second peaks for both the left foot and the right foot separately, allowing for a more comprehensive understanding of the impact of backpack load and walking duration on gait dynamics.

Procedure for Data Collection

The subjects were gathered in the biomechanics lab at IGIPSS, University of Delhi. Prior to data collection, informed consent and release of liability forms were obtained from the guardians. The entire data collection procedure was thoroughly explained to the subjects to ensure they understood the process. The subjects were introduced to five backpack load conditions, that are B1 = backpack load of 0 % of bodyweight (no additional load in backpack); B2 = backpack load of 8 % of bodyweight; B3 = backpack load of 12 % of bodyweight; B4 = backpack load of 16 % of bodyweight; B5 = backpack load of 20 % of bodyweight, which were carried for extended duration of time with the purpose of recording the force distribution at specific periods of time (T1 = recording at zero-minute; T2 = recording at fifth minute; T3 = recording

at tenth minute; T4 = recording at fifteenth minute; T5 = recording at twentieth minute).

Statistical Analysis

For data analysis, the data recorded with the pressure platform software was exported to Excel for further statistical analysis, including mean, standard deviation, coefficient of variation, and t-ratio. A t-test was conducted with the significance level set at 0.05. The results were visually represented using two-dimensional line diagrams for clearer interpretation.

Results

The following Table 1 provides the descriptive statistics for the force at the first peak of the left foot, measured with the selected backpack loads and at the designated recording times.

The following Table 2 presents the descriptive statistics for the force at the second peak of the left foot, measured across various backpack loads and at selected recording times.

The following Table 3 provides the descriptive statistics for the force at the first peak of the right foot, measured with the selected backpack loads and at the designated recording times.

The following Table 4 provides the descriptive statistics for the force at the second peak of the right foot, measured with the selected backpack loads and at the designated recording times.

Table 1. Descriptive statistics of the force at first peak of left foot with the selected backpack loads at selected recording times

		Force (Newton) at First Peak of Left Foot							
S.N.	Bag Time	B1	B2	B3	B4	B5	Mean	SD	CV
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD			
1	T1	361.37 $\pm$ 88.38	398.09 $\pm$ 96.78	410.48 $\pm$ 90.80	430.71 $\pm$ 96.16	434.26 $\pm$ 102.94	406.98	95.01	23.35
2	T2	367.43 $\pm$ 87.25	403.31 $\pm$ 88.60	410.99 $\pm$ 95.46	426.56 $\pm$ 98.72	430.42 $\pm$ 101.00	407.74	94.20	23.10
3	T3	367.21 $\pm$ 87.03	399.09 $\pm$ 91.36	411.79 $\pm$ 91.01	425.84 $\pm$ 99.17	433.54 $\pm$ 94.04	407.49	92.52	22.71
4	T4	367.37 $\pm$ 87.34	399.13 $\pm$ 84.29	415.52 $\pm$ 95.09	429.84 $\pm$ 100.35	433.51 $\pm$ 99.79	409.07	93.37	22.83
5	T5	371.05 $\pm$ 84.84	400.22 $\pm$ 85.80	409.33 $\pm$ 87.35	423.54 $\pm$ 95.95	437.49 $\pm$ 98.56	408.33	90.50	22.16
		366.89 $\pm$ 86.96	399.97 $\pm$ 89.36	411.62 $\pm$ 91.94	427.30 $\pm$ 98.07	433.85 $\pm$ 99.27			
	CV	23.70	22.34	22.34	22.95	22.88			

Note: T1 = Recording at 0 minute; T2 = Recording at fifth minute; T3 = Recording at tenth minute; T4 = Recording at fifteenth minute; T5 = Recording at twentieth minute; B1 = Backpack Load of 0 % of Body Weight (No bag); B2 = Backpack Load of 8 % of Body Weight; B3 = Backpack Load of 12 % of Body Weight; B4 = Backpack Load of 16 % of Body Weight; B5 = Backpack Load of 20 % of Body Weight

Table 2. Descriptive statistics of the force at second peak of left foot with the selected backpack loads at selected recording times

		Force (Newton) at Second Peak of Left Foot							
S.N.	Bag Time	B1	B2	B3	B4	B5	Mean	SD	CV
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD			
1	T1	369.98 $\pm$ 82.12	396.45 $\pm$ 84.18	408.92 $\pm$ 83.60	428.24 $\pm$ 92.58	440.13 $\pm$ 93.21	408.75	87.14	21.32
2	T2	371.65 $\pm$ 81.91	406.12 $\pm$ 85.07	416.77 $\pm$ 82.96	425.12 $\pm$ 100.60	437.81 $\pm$ 96.20	411.49	89.35	21.71
3	T3	372.97 $\pm$ 78.43	406.21 $\pm$ 81.31	416.39 $\pm$ 83.02	426.83 $\pm$ 91.15	441.27 $\pm$ 102.63	412.73	87.31	21.15
4	T4	374.00 $\pm$ 77.66	402.25 $\pm$ 84.46	419.18 $\pm$ 82.60	430.58 $\pm$ 89.86	440.45 $\pm$ 97.45	413.29	86.41	20.91
5	T5	375.02 $\pm$ 79.24	401.71 $\pm$ 88.26	415.89 $\pm$ 84.96	424.05 $\pm$ 83.63	439.14 $\pm$ 95.30	411.16	86.28	20.98
		372.72 $\pm$ 79.87	402.55 $\pm$ 84.66	415.43 $\pm$ 83.43	426.96 $\pm$ 91.56	439.76 $\pm$ 96.96			
	CV	21.43	21.03	20.08	21.45	22.05			

Note: T1 = Recording at 0 minute; T2 = Recording at fifth minute; T3 = Recording at tenth minute; T4 = Recording at fifteenth minute; T5 = Recording at twentieth minute; B1 = Backpack Load of 0 % of Body Weight (No bag); B2 = Backpack Load of 8 % of Body Weight; B3 = Backpack Load of 12 % of Body Weight; B4 = Backpack Load of 16 % of Body Weight; B5 = Backpack Load of 20 % of Body Weight

Table 3. Descriptive statistics of the force at first peak of right foot with the selected backpack loads at selected recording times

		Force (Newton) at First Peak of Right Foot					Mean	SD	CV
S.N.	Bag Time	B1	B2	B3	B4	B5			
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD			
1	T1	379.61 $\pm$ 85.43	408.71 $\pm$ 96.23	424.99 $\pm$ 90.47	449.50 $\pm$ 91.17	462.67 $\pm$ 96.38	425.09	91.94	21.63
2	T2	378.46 $\pm$ 88.08	411.77 $\pm$ 88.22	421.20 $\pm$ 90.11	438.86 $\pm$ 99.90	443.76 $\pm$ 107.02	418.81	94.66	22.60
3	T3	382.47 $\pm$ 83.43	409.20 $\pm$ 90.33	422.10 $\pm$ 86.99	446.99 $\pm$ 106.96	451.46 $\pm$ 96.33	422.44	92.81	21.97
4	T4	376.05 $\pm$ 91.56	407.93 $\pm$ 91.31	423.98 $\pm$ 90.17	444.92 $\pm$ 101.57	455.56 $\pm$ 97.26	421.69	94.37	22.38
5	T5	386.65 $\pm$ 83.34	410.46 $\pm$ 88.22	422.35 $\pm$ 91.94	446.13 $\pm$ 106.88	452.46 $\pm$ 101.88	423.61	94.45	22.30
		380.65 $\pm$ 86.37	409.61 $\pm$ 90.86	422.92 $\pm$ 89.93	445.28 $\pm$ 101.30	453.18 $\pm$ 99.77			
	CV	22.69	22.18	21.26	22.75	22.02			

Note: T1 = Recording at 0 minute; T2 = Recording at fifth minute; T3 = Recording at tenth minute; T4 = Recording at fifteenth minute; T5 = Recording at twentieth minute; B1 = Backpack Load of 0% of Body Weight (No bag); B2 = Backpack Load of 8% of Body Weight; B3 = Backpack Load of 12% of Body Weight; B4 = Backpack Load of 16% of Body Weight; B5 = Backpack Load of 20% of Body Weight

Table 4. Descriptive statistics of the force at second peak of right foot with the selected backpack loads at selected recording times

		Force (Newton) at Second Peak of Right Foot					Mean	SD	CV
S.N.	Bag Time	B1	B2	B3	B4	B5			
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD			
1	T1	363.42 $\pm$ 75.93	391.63 $\pm$ 83.45	407.72 $\pm$ 80.17	421.35 $\pm$ 83.55	438.87 $\pm$ 89.24	404.60	82.47	20.38
2	T2	365.60 $\pm$ 76.29	398.54 $\pm$ 84.85	412.64 $\pm$ 81.92	418.41 $\pm$ 85.14	426.58 $\pm$ 105.15	404.35	86.67	21.43
3	T3	366.68 $\pm$ 75.30	395.89 $\pm$ 85.15	417.38 $\pm$ 82.59	421.34 $\pm$ 83.76	437.62 $\pm$ 91.89	407.78	83.74	20.54
4	T4	366.94 $\pm$ 77.44	398.43 $\pm$ 83.45	411.49 $\pm$ 83.81	425.54 $\pm$ 85.44	436.01 $\pm$ 96.90	407.68	85.41	20.95
5	T5	373.25 $\pm$ 73.45	399.86 $\pm$ 82.74	413.96 $\pm$ 84.37	422.64 $\pm$ 83.95	433.91 $\pm$ 95.42	408.72	83.98	20.55
		367.17 $\pm$ 75.68	396.87 $\pm$ 83.93	412.63 $\pm$ 82.57	421.85 $\pm$ 84.37	434.60 $\pm$ 95.72			
	CV	20.61	21.15	20.01	20.00	22.02			

Note: T1= Recording at 0 minute; T2 = Recording at fifth minute; T3 = Recording at tenth minute; T4 = Recording at fifteenth minute; T5 = Recording at twentieth minute; B1 = Backpack Load of 0% of Body Weight (No bag); B2 = Backpack Load of 8% of Body Weight; B3 = Backpack Load of 12% of Body Weight; B4 = Backpack Load of 16% of Body Weight; B5 = Backpack Load of 20% of Body Weight

Table 5. Comparison between mean of force at first peak of left foot and right foot with the selected backpack loads at selected recording times

Mean Peak Force (Newton) at Selected Backpack Loads						
Variables	B1	B2	B3	B4	B5	Total
Left Foot	366.89	399.97	411.62	427.30	433.85	2039.00
Right Foot	380.65*	409.61*	422.92*	445.28*	453.18*	2111.64*
Difference b/w Left & Right Foot	-13.76	-9.64	-11.3	-17.98	-19.33	-72.01
Total	747.54	809.58	834.54	872.58	887.03	4151.27
Average	373.77	404.79	417.27	436.29	443.51	2075.63

*Note 't' value found to be significant at 0.05 level

According to Table 5 and Figure 2, the mean of force at first peak of right foot is more as compared to mean of force at first peak of left foot. It is also observed that with the increase in backpack load, the mean of force (in newton) at peak also increases at left and right foot. The t-test analysis revealed significant differences in the mean forces at the first peak between the left and right foot at varying backpack loads, with significance established at the 0.05 level.

According to Table 6 and Figure 3, the mean of force at first peak of left foot is more as compared to mean of force at first peak of right foot. It has also been observed that as backpack load increases, the mean peak force (in newtons) rises correspondingly, both, at left and right foot. The t-test showed significant differences in the mean forces at the

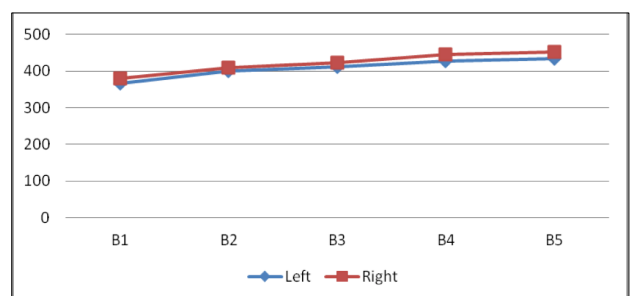


Fig. 2. Comparison between mean of force at first peak of left foot and right foot with the selected backpack loads at selected recording times

Table 6. Comparison between mean of force at second peak of left foot and right foot with the selected backpack loads at selected recording times

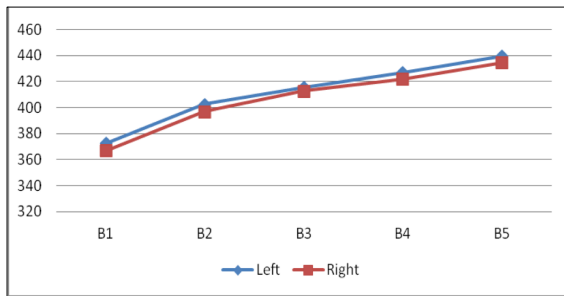
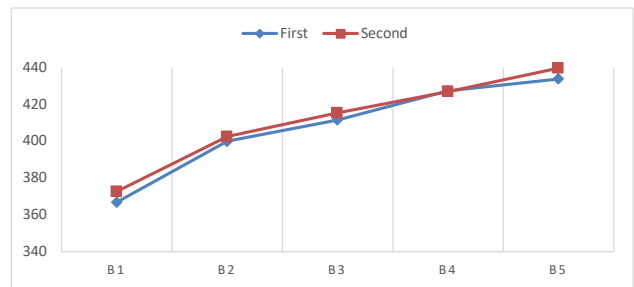
Mean Peak Force (Newton) at Selected Backpack Loads of Left Foot and Right Foot						
Variables	B1	B2	B3	B4	B5	Total
Left Foot	372.72*	402.55*	415.43*	426.96*	439.76*	2057.42*
Right Foot	367.17	396.87	412.63	421.85	434.6	2033.12
Difference b/w Left & Right Foot	5.55	5.68	2.8	5.11	5.16	24.30
Total	739.89	799.42	828.06	848.81	874.36	4090.54
Average	369.945	399.71	414.03	424.405	437.18	2045.27

*Note 't' value found to be significant at 0.05 level

Table 7. Comparison between mean of force (newton) at first and second peak of left foot with the selected backpack loads at selected recording times

Mean Peak Force at Selected Backpack loads of First and Second Peak of Left Foot						
Variables	B1	B2	B3	B4	B5	Total
Force at First Peak	366.89	399.97	411.62	427.3	433.85	2039.63
Force at Second Peak	372.72*	402.55*	415.43*	426.96*	439.76*	2057.42*
Difference b/w Force at First & Second Peak	-5.83	-2.58	-3.81	0.34	-5.91	-17.79
Total	739.61	802.52	827.05	854.26	873.61	4097.05
Average	369.805	401.26	413.525	427.13	436.805	2048.525

*Note 't' value found to be significant at 0.05 level

**Fig. 3.** Comparison between mean of force at second peak of left foot and right foot with the selected backpack loads at selected recording times**Fig. 4.** Comparison between mean of force at first and second peak of left foot with the selected backpack loads at selected recording times**Table 8.** Comparison between mean of force (newton) at first and second peak of right foot with the selected backpack loads at selected recording times

Mean Peak Force at Selected Backpack loads of First and Second Peak of Right Foot						
Variables	B1	B2	B3	B4	B5	Total
Force at First Peak	380.65*	409.61*	422.92*	445.28*	453.18*	2111.64*
Force at Second Peak	367.17	396.87	412.63	421.85	434.6	2033.12
Difference b/w First & Force at Second Peak	13.48	12.74	10.29	23.43	18.58	78.52
Total	747.82	806.48	835.55	867.13	887.78	4144.76
Average	373.91	403.24	417.775	433.565	443.89	2072.38

*Note 't' value found to be significant at 0.05 level

second peak between the left and right foot across different backpack loads, with statistical significance at the 0.05 level.

As shown in Table 7 and Figure 4, the mean of force at the second peak is higher compared to the first peak of the left foot. Additionally, the mean of force at both the first and second peaks increase as the backpack load on the left foot increases. The differences between the first and second peak forces of the left foot were found to be statistically significant at the 0.05 level, as indicated by the t-test results.

As indicated in Table 8 and Figure 5, the mean of force at the first peak of the right foot is higher compared to the second peak. Additionally, both the first and second peak forces increase as the backpack load on the right foot increases. The t-test results demonstrated significant differences between the first and second peak forces of the right foot, with significance at the 0.05 level.

According to Table 9, the mean of force at the first peak of the right foot is greater than the mean of force at the sec-

Table 9. Comparison between mean of force (newton) at first and second peak of right foot and left foot as a whole*

Mean of Force (Newton) at First and Second Peak of Right Foot and Left Foot as a Whole*				
Peak Force/Foot	Right Foot	Left Foot	Total (Newton)	Sig.
Force at First Peak (Newton)	2111.64	2039.63	4151.27	0.002
Force at Second Peak (Newton)	2033.12	2057.42	4090.54	0.001
Total (Newton)	4144.76	4097.05	8241.81	

*Whole = All backpack loads and recording times, collectively

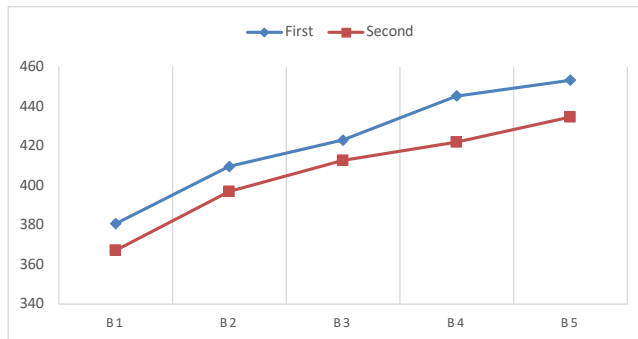


Fig. 5. Comparison between mean of force at first and second peak of right foot with the selected backpack loads at selected recording times

ond peak of the left foot across the selected backpack loads and recording times.

Table 10. Result of paired sample t-test at first and second peak of right foot and left foot as a whole*

Force (Newton) at First and Second Peak of Right Foot and Left Foot as a Whole*				
Peak Force	MD	SED	t-value	p-value (Sig. 2-tailed)
Force at First Peak	-14.402	1.868	-7.709	0.002
Force at Second Peak	4.860	0.526	9.230	0.001

*Whole = All backpack loads and recording times, collectively.

Table 10 presents the results of a paired sample t-test comparing the forces (in Newtons) at the first and second peaks of the right and left feet, treated collectively across all backpack loads and recording times. The t-test evaluates whether there is a statistically significant difference in the peak forces between these two time points. For the first peak force, the mean difference is -14.402 Newtons, with a standard error of difference (SED) of 1.868. The t-value is -7.709, and the p-value is 0.002, which is statistically significant at the 0.05 level. For the second peak force, the mean difference is 4.860 Newtons, with an SED of 0.526. The t-value is 9.230, and the p-value is 0.001, which also shows statistical significance. Overall, these results demonstrate significant changes in force between the feet at both peaks, emphasizing how backpack load and timing affect foot force dynamics.

Discussion

The aim of the present study was to investigate the influence of different backpack loads carried by the students on forces at different peaks of left and right foot during walking gait. The results of this study indicate that an increase in

backpack load significantly affects the peak forces during the gait cycle. As observed, the mean of force at both the first and second peaks of the left and right feet increased with heavier backpack loads. The t-test confirmed that these increases in peak forces across different backpack loads were statistically significant at the 0.05 level, highlighting the biomechanical impact of heavier loads on walking gait. This finding is consistent with the literature, which reports that carrying backpacks exceeding 10% of body weight increases ground reaction forces, thereby placing additional strain on the musculoskeletal system (Ahmad & Barbosa 2019; Pau et al. 2015).

Interestingly, the study revealed an asymmetry between the mean of forces on the right and left feet, with the right foot dominating at the first peak and the left foot dominating at the second peak. The observed differences in mean of forces between the left and right foot were also found to be statistically significant, as confirmed by the t-test at the 0.05 level, suggesting that carrying a backpack may induce gait asymmetry, potentially leading to altered posture and gait mechanics. Such asymmetry may contribute to the development of musculoskeletal disorders in children, as imbalances in force distribution can lead to compensatory mechanisms, increasing the risk of injury (Mackenzie et al. 2003; Rai & Agarwal 2013).

Furthermore, the incremental increase in mean of force at peaks, across the different recording times suggests that the effects of backpack loads may compound over time, emphasizing the need for caution when children carry heavy backpacks for extended periods. The t-test results further validated that these cumulative effects of backpack loads over time were statistically significant. Reinforcing the need for regulated backpack weight to prevent long-term biomechanical strain. This finding aligns with research suggesting that prolonged load carriage leads to greater biomechanical stress and fatigue (Castro et al. 2013). In high-intensity sports, exercises like Nordic hamstring curls are essential for strengthening the hamstrings and developing eccentric strength, which helps reduce injury risk. The hamstrings play a key role in controlling heel strike and the swing phase during walking and running. This is particularly relevant in our study on the effects of backpack loads on peak forces during walking gait, as strong hamstrings are crucial for managing altered gait dynamics and preventing muscle strain (Islam et al., 2024).

There was an overall increment in the mean of force at first peak when the subjects walked with different backpack loads. It was reported by Barbosa et al. (2019) that there was increase in first peak magnitude of class fifth grade students during walking with different backpack loads. Contradictory to the study by Behmaram et al. (2022) who stated an increase in second peak ground reaction force with increase in backpack loads as one has to overcome greater force for moving forward when backpack load increases. Contra-

diction between Barbosa et al. (2019) and Behmaram et al. (2022) requires further investigation.

In light of these findings, it is critical to establish guidelines for safe backpack loads for schoolchildren. It was reported that carrying a backpack weighing 10% of body weight is too heavy for students aged between ten and fifteen years and affects their normal cervical and shoulder posture alignment (Chansirinukor et al., 2001). Similarly, Husain et al. (2024) found that heavier backpack loads and longer walking durations significantly affected the timing of peak forces in the gait cycle of schoolboys, underscoring the need for further research on the effects of backpacks on children's gait. A commonly recommended limit of 10-15% of body weight may still be too heavy, especially for younger students, as even the lightest load in the present study (8% backpack load of bodyweight) resulted in a measurable increase in peak forces.

This study was limited to male students aged 10 to 12 years, and future research should include female participants to explore gender-based differences in gait biomechanics. The controlled experimental environment may not fully replicate natural walking conditions over longer distances. However, the study's strengths include its systematic examination of multiple backpack loads on walking gait using a precision pressure platform, providing reliable data on peak forces. The findings emphasize the need to regulate backpack loads to protect children's musculoskeletal health, and future research should investigate long-term effects and explore interventions like ergonomic backpack designs and educational programs.

Conclusions

The study concludes that the increasing backpack loads lead to higher mean of forces at both the first and second peaks of the gait cycle, particularly in the right foot at the first peak and the left foot at the second peak. The asymmetry observed between the two feet suggests that prolonged backpack use with heavy loads can contribute to posture and gait imbalances, which may increase the risk of musculoskeletal problems. Additionally, future research should investigate the long-term effects of backpack carriage on musculoskeletal health and explore potential interventions, such as ergonomic backpack designs and educational programs for students and parents.

Acknowledgment

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Conflicts of Interest

The authors declare no conflicts of interest.

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Розуміння впливу окремих навантажень рюкзака з певною тривалістю носіння на показники максимальних зусиль під час пішої ходьби у хлопчиків шкільного віку

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 9 с., 10 табл., 5 рис., 33 джерела.

Історія питання. Рюкзаки зазвичай використовуються учнями для перенесення шкільного приладдя. Однак збільшен-
ня обсягів навантаження рюкзака може призвести до негативного впливу на стан здоров'я та поставу, зокрема, через зміну
динаміки ходи. Показник максимальних зусиль є критично важливою змінною в контексті розуміння механіки ходи, на яку
суттєво впливають навантаження під час носіння. Тому вкрай важливо дослідити зміни показників максимальних зусиль
при різних (зростаючих) навантаженнях рюкзака і тривалості його носіння.

Мета дослідження. Метою дослідження було вивчити вплив різних обсягів навантажень рюкзака під час носіння протягом різної тривалості на показники зусиль, що виникають на першому та другому пікових значеннях тиску лівої та правої стоп під час циклу пішої ходьби у хлопчиків шкільного віку.

Матеріали та методи. Суб'єктами дослідження були особи ($n = 85$) віком від 10 до 12 років з Національного столичного регіону Делі, яких було відібрано за методом рандомізації. Показники зусиль на першому та другому піках вимірювали за допомогою платформи для визначення тиску ZebrisInc, що підтримується програмним забезпеченням Win FDM-S (Німеччина). Проаналізовано п'ять умов навантаження рюкзака, а саме: B1 = навантаження рюкзака 0 % від маси тіла (без додаткової ваги в рюкзаку); B2 = навантаження рюкзака 8 % від маси тіла; B3 = навантаження рюкзака 12 % від маси тіла; B4 = навантаження рюкзака 16 % від маси тіла; і B5 = навантаження рюкзака 20% від маси тіла, на п'яти наступних записах часу: T1 = запис на нульовій хвилині ходьби; T2 = запис на п'ятій хвилині ходьби; T3 = запис на десятій хвилині ходьби; T4 = запис на п'ятнадцятій хвилині ходьби; T5 = запис на двадцятій хвилині ходьби. Статистичний аналіз включав оцінку середнього значення, стандартного відхилення, коефіцієнта варіації та t-співвідношення. Рівень значущості t-критерію становив 0,05.

Результати. Результати дослідження показали, що збільшення обсягів навантаження рюкзака призводить до зростання показників максимальних зусиль як на першому, так і на другому піках циклу ходи. Під час першого піку права стопа розвивала підвищені показники сили, тоді як на другому піку домінувала ліва стопа. Крім того, встановлено, що тривале носіння навантаження також призводить до збільшення максимальних зусиль. T-критерій на основі парної вибірки виявив значні відмінності між першим і другим піками, із середньою різницею — 14,402 Н ($p = 0,002$) для першого піку і 4,860 Н ($p = 0,001$) для другого піку.

Висновок. За результатами дослідження було визначено, що збільшення навантаження рюкзака значно підвищує середнє значення максимальних зусиль під час пішої ходьби, що може призвести до порушення постави та асиметрії ходи. Отримані дані свідчать про необхідність регулювання навантаження рюкзака з метою запобігання виникненню потенційних проблем з опорно-руховим апаратом у дітей.

Ключові слова: рюкзак, перший пік, сила, цикл ходи, перенесення навантаження, другий пік, піша ходьба.

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Implications and Critiques of Quantitative Research: A Systematic Review

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Abstract

Objectives. The study aimed to critically examine challenging notions and attributes embedded with quantitative research from a social science perspective.

Materials and methods. Following a systematic review, this study assessed key gaps and contestations revealed in scientific readings published by highly indexed journals and more cited referred texts. The primary analytical question included conceptualizing quantitative methods and highlighting different dimensions of ontology, validity, reliability, generalizability, and ethical implications.

Results. The quantitative method is widely used in most scientific fields, translating the research findings into strategic analysis through statistical and experimental frameworks. Despite this scope, the results of this study indicate that the quantitative method has some limitations and dilemmas, which could limit our appreciation and understanding of human behaviour and social phenomena in the subjective world. While adding to the base of empirical knowledge, quantitative research has been criticized for an inadequate approach to capturing complex social phenomena, dependence on rigid assumptions, and vulnerability to contextual factors. Reflecting on these limitations of current quantitative methods informs both directions for advancing existing measurement approaches and integrating alternative strategies.

Conclusions. This study concludes that the quantitative method's implications are rational, though not universal. The deterministic approach of quantitative methodology can dilute the understanding of the subjective world due to its inclination towards absolute realities. Therefore, the study underscores the need for methodological pluralism, encouraging scholars, researchers, and students in social sciences and related fields to be open-minded and receptive to alternative research approaches and multi-method strategies for a more comprehensive understanding of human behaviour and social phenomena.

Keywords: research, quantitative methodology, positivism, critique and implications.

Introduction

Quantitative research, with its systematic approach, investigates a particular research problem by collecting quantifiable data and employing statistical, mathematical, or computational techniques. This method is rooted in a positivist approach to knowledge dissemination offering a hallmark of different tools and techniques with scientific scales of measurement (Jamieson et al., 2023; Sapkota, 2024). The quantitative techniques excel in empirical inquiry based on numerical data and statistical tests, making them a reliable choice in all fields. Their strength lies in establishing cause and effect, patterns and forecasting, making them optimal for psychology, economics, public health and education. The capacity to generate numbers has elevated quantitative methods to

a standard status, widely accepted in various academic and professional fields-especially in evidence-based policy-making and practice. Therefore, a scientific definition of quantitative methodology can be confidently asserted as:

“any methodological approach or methods that rely on using some structured instrument, like a survey or an experiment in which the researcher can collect big data-sets so they can have quantification of data to analyze the objective world – and provide results that will broadly generalize the research findings or conclusions with deductive reasons.”

Nevertheless, despite how effective these methods can be, quantitative research methods come with glaring criticisms. This approach has been criticized by scholars and practitioners alike for restricting the range of research findings and oversimplifying complex social phenomena. This

overconfidence in transforming methodological positivism is a belief that the only authentic knowledge is scientific and that such knowledge can only come from the positive affirmation of theories through strict scientific methods and guidelines. It is based on the widespread objectivity of numeric data, which needs valid support and exploration of the supposed reality and empirical irreducibility to human experience or social context in the making. Critics further note that this type of research cultivates a severance from the lived experiences of people and communities, resulting in shallow findings and often disconnected from the complexities of human behaviour and social interaction (Rudd et al., 2021). This detachment invites doubt over the rigour and relevance of many quantitative findings, mainly where broader issues such as public policy, community sentiments, collective behaviour and intrinsic human values include subjective experiences and contextual factors.

The paper aims to systematically review the critical criticisms made of quantitative research for gaps and shortcomings in methodology and assumptions. The study aims to respond to these critiques and clarify their implications for research findings whilst reviewing literature across social sciences, health sciences and educational research. Additionally, this paper will eventually contribute to the ongoing debate on methodological improvement in quantitative research and the positivism paradigm. It advocates for a more integrative view that combines quantitative granular insights with complementary qualitative approaches, inspiring a new perspective. This integrative view offers hope for the future of research, leading to more nuanced insights that are less disconnected from practice and policy.

Materials and Methods

This systematic review adopts a qualitative design using secondary sources, appraising academic papers, critiques and research disputation on quantitative methods. Studies were included according to selection criteria that demanded an explicit critique of quantitative methodologies centring on validity, reliability and generalizability issues, reductionism, and ethical considerations. The review was enriched by a thorough search of scientific readings and studies from JSTOR, PubMed, and Google Scholar, covering literature published between 2000 and 2023.

The publications, drawn from a diverse range of disciplines including psychology, sociology, economics, development studies, public health, and education, foster an interdisciplinary dialogue on the implications and criticisms of quantitative research. A critical analysis of articles was vetoed, and themed criteria were coalesced into categories. Through consideration of prominent theoretical traditions, including those offered by Lincoln and Guba (1985), Sardana et al. (2023) and Strunk (2023), this critique suggests that the limitations of quantitative methodologies may result in particular difficulties in capturing complex social phenomena.

Results

Conceptualization of the quantitative research

Quantitative research is a precise tool for exploring and assessing objective realities that can be measured. This precision enables us to establish patterns, cause and effect rela-

tionships, and predict outcomes. The method, which typically utilizes formal techniques such as surveys, experiments, and observational studies, gathers data that can be statistically assessed (Fischer et al., 2023). The goal is to maintain objectivity and generalizability, allowing researchers to make inferences that can be applied across other settings and populations. Quantitative research aims to reduce biases, ensuring replicable and valid findings by using standardized measures in terms of pre-defined variables and indicators, structured questionnaires and a deduction-oriented reasoning approach.

Quantitative research, however, is guided by certain assumptions that heavily influence its design and interpretation. A major assumption is that the phenomenon can be measured and quantified, projecting the non-numeric abstract world into a numeric and quantified world of simple numbers. Furthermore, quantitative research assumes objectivity, allowing researchers to remain neutral when gathering and analyzing data. This scientific rigour is essential in ensuring that the research process does not contaminate the results and that the results are still meaningful. Moreover, quantitative researchers broadly assume that relationships between variables can be revealed through systematic inquiry and statistical methods, resting on the belief in stable patterns.

The second assumption taken for granted in quantitative research is the determinism of methodological instruments; that is, some factors are thought to affect, condition and orient the outcomes predictably. It is this assumption that underlies the use of causal-comparative and experimental designs, which are research designs that allow researchers to establish cause-and-effect relationships. In these designs, the independent (treatment, intervention) variables are manipulated by researchers so that they can assess their impact on dependent (outcome) variables. These kinds of causal designs rest on the assumption that knowledge of these is helpful for the prediction of future behaviour or outcomes. However, this assumption has been criticized for oversimplifying different and complex social scenarios and human behaviour. Critics of the quantitative paradigm in social science research, as discussed by Saldaña (2021), state that this focus on causality can neglect the role of external factors and other social dynamics that interact with one another to affect each other. Eventually, it renders the complete story absent from models testing a specific variable relationship between independent and dependent variables, wherein adding every conceivable factor is not feasible. Therefore, it is critical to remember that conceptualizations and assumptions found in quantitative research, while deeply theoretically grounded, may need to be taken a critical eye before being forcefully used as the basis for some phenomena or relationships.

Ontological and epistemological critique

Ontological and epistemological critiques against quantitative methodology have gained increasing attention in paradigmatic debates. For example, quantitative research is generally based on a realist ontology, a philosophical position that posits the existence of an objective reality independent of human perception, which assumes that social phenomena are objective and external to us and can be measured by others in exact terms. The quantitative research paradigm

holds the ontology of positivism, which is that generalization and replication of objective realities are expected to be commonalities (Zyphur & Pierides, 2020b). Instead, qualitative researchers and constructivists tend to explore differences in the realities of the subjective world. Thus, the quantitative perspective presumes a distinction between the observer and the observed, ignoring that human experience and social reality are subjective. It has been said that this method oversimplifies the complexity of social phenomena and turns them into zeroes and ones, disregarding cultural context and social science at large (Tabron & Thomas, 2023). This has led the ontological stance of quantitative research to come under attack for ignoring the interpretive components essential to comprehending social contexts, cultural constructs and perceptions of people.

For instance, in terms of epistemology-quantitative methods, because they come from social statistics, privilege objective knowledge but have deep-seated trouble accepting subjective contexts or descriptions of the society where we live and interact. This also aligns with a positively oriented framework of establishing universal laws and generalizable findings through empirical measurement. However, opponents argue that this dependence on statistics can create superficial views of social phenomena, as it does not account for the context-sensitive socio-structural factors that inform individual and collective action. That is why a quantitative analysis might only be able to show some patterns of educational success and failure from year to year by demographic group. In contrast, a qualitative study, with its unique ability to analyze the socio-cultural and economic dynamics behind the trends, is invaluable in understanding the full complexity of social issues. The epistemological critique thus reveals the shortcomings of quantitative research in dealing with human behaviour and social complexity, calling for a pluralistic perspective that values qualitative insights and situational specificity in creating knowledge. Combining several epistemologies within these approaches can provide nuanced details of the complexities of social issues that will contribute significantly to a particular field of inquiry.

Limitations in validity and reliability

Validity and reliability are central measures of methodological rigour for quantitative research (Duckett, 2021; Sürücü & Maslakci, 2020). However, critics have suggested that adherence to these principles leads such research too often toward narrowly focused interpretations (Maxwell, 2016). Positivist approach, an epistemological basis of most quantitative research methods, denies interpreting human experiences as understood in qualitative terms (Lincoln & Guba, 1985). Consider the following – emotionally complex states, the nuances in different cultures geographically stretched apart and social contexts behind how human beings behave and are inclined to think and feel are often simplified and quantified. In this way, reductionism might yield statistically valid findings that are nevertheless not grounded in the lived experiences of participants. Additionally, the focus on reliability may also result in researchers compromising richness — or paying insufficient attention to the meaningful aspects of data in favour of finding consistent answers through methods of consistency (argument). Thus, if the nuances of human

behaviour become less critical because they are not statistically significant, quantitative studies may be valid but will always lack much of what makes them attractive – so long as we ignore the idea that a specific number or magnitude can theoretically represent every human experience.

Furthermore, depending on controlled variables and statistical methods, it creates an illusion of objectivity without considering contextual factors that influence the behaviour of humans. Some critics point out that the quantitative approach focuses on controlling and isolating variables in experimental settings – a process that ignores how socialization works through ongoing participation (by humans with agency) embedded in multilayered contexts. This disconnects the perceived realities and actual realities; which one is valid is always contested, though. Nevertheless, the observers (including researchers) cannot change the ‘independent existence’ of the reality embedded with the phenomenon we investigate. For example, the results of an experiment could provide insights into issues in various social contexts or populations but then differ significantly when attempts are made to apply them. In addition, the quantitative hypothesis testing model may hinder researchers from pursuing emergent themes or unexpected findings that do not fit predetermined parameters. Consequently, the definition of social phenomena is sometimes unwittingly restricted by the rigid definitions required in quantitative research-suggesting a greater need for integrated approaches (one combining rigorous quantitative analysis with qualitative understanding) to tap into such complex human and socially situated behaviours effectively.

Reductionism and contextual oversights

Some critics suggest that quantitative research is reductionist, taking substantial social complexities and rendering them into un-hierarchic variables. Critics like Hodge (2020) and Sapkota (2024) and Verschuren (2001) argue that this reductionism has the adverse consequence of decontextualizing phenomena, constraining generalizability and robustness of findings. For example, a typical quantitative public health study that reports the incidence of a particular disease may not capture other factors, such as poverty and cultural beliefs directly linked to it. This narrow approach can produce results from researchers who must reflect the realities of those suffering and create a gap in understanding. If interpreted as the work of a few individuals doing well, the consequence will be inappropriate policies with likely damaging effects designed to minimize incentives and competition rather than structural reasons behind these high-impact health inequalities.

Furthermore, the focus on data generalization in quantitative research often leads to the unintentional perpetuation of biases and stereotypes. Outliers or exceptional cases, such as smaller groups or nonstandard experiences, may be effectively ignored in larger datasets. For instance, in educational research, the averages generated by quantitative methods might obscure the unique stories of students with disabilities or those who are members of a nontraditional group. When researchers anchor their work in statistical averages, they may inadvertently reinforce the biases and stereotypes they aim to counteract, masking individual experiences under the broad brush of flawed and limiting quantitative data. These imbalances, however, perpetuate inequities, as schools use

group data to direct their services to an entire population instead of tailoring them to the unique needs of each student. Thus, quantitative research, by reducing understanding to a shallow level of detail, can perpetuate society's systemic injustices due to its inability to derive meaning from context.

Generalizability and sample limitations

Quantitative research is frequently highly generalizable, aspiring to make inferences on larger populations of individuals in different circumstances. Quantitative generalization depends on sampling methods and research design in use (Keyzers et al., 2019). However, critics such as Bryman (2012) point out that problematic generalizations can occur when studies relate to samples that are biased or not representative of the wider population. For example, in education, studies that relied on survey responses may inadvertently attract certain demographic groups more than others, skewing the representation from some socio-economic or cultural backgrounds. They are raw from a specific school district, which might not reflect the diversity of the population or the survey will have some bias towards students with better academics, and therefore, results will be skewed. Therefore, results stemming from these samples must be more generalizable to the broader population.

These critics say that quantitative research lacks external validity due to specific methodological issues such as biased sampling, inadequate sample size, or flawed research design, which make the findings unable to inform policy or practice effectively (Queirós et al., 2017). Research that does not accurately reflect the diversity of a population can lead to misleading assumptions and, ultimately, solutions that only help part of a population by leaving parts out. For instance, we might run a program to educate practitioners based on findings from a non-diverse sample and cite these results as the reason that pupils from underrepresented communities are not gaining experience with work-related learning; our intervention may address one population only — depriving an essential diversity of its students who go into gainful employment of the skills they need — and effectively widen inequality rather than lessen it. Furthermore, when policymakers use these generalized findings to implement decisions, there is a potential risk that such policies will not fit all and may lead to moving multiple levers with solutions dealing with all stakeholders involved. Therefore, quantitative methods often have minimal utility in the real-world context without appropriate research design and representative sampling.

Ethical concerns and participant detachment

Ethical issues in quantitative research may be played down because of the dominant nature of quantified (i.e. number-based) output and statistical significance. It can lead researchers to prioritize data collection and analysis at the expense of understanding participants' lived experiences, a crucial aspect that should not be overlooked (Zyphur & Pierides, 2017). In areas like psychology and health, where quantitative approaches often dominate, the standardization implicit in these procedures and protocols can also lead to an insensitivity toward the specific situation of each participant. Institutional review boards (IRBs) protect study participants'

rights and ensure they provide informed consent but often do not consider the ethical implications of data collection more generally. The downside is that researchers treat users as mere statistics rather than individual users with special needs and experiences.

According to Guba and Lincoln (1994), participatory ethics is often forgotten in quantitative studies, as the more formalized structure of quantitative research creates a barrier between researchers and the people whose lives they are trying to study. Such shelving of the deeper truths of participants can have a probability impact by focusing on outcomes, treating research like an equation, and avoiding nuance about how lives have been affected. In one instance, a study that evaluated the effects of a novel health intervention reported statistically significant benefits in numeric outcomes but did not capture any participant's hurdles or motivations nor the community contextual factors that would aid readers in interpreting this particular data — each participant's whole person experience with the behaviour being studied. This lack of nuance in the results hinders their interpretation and application in practice, leading to perceived successes of dubious validity. Therefore, a more nuanced approach, incorporating qualitative components or participatory methods, is needed to guide the ethical consciousness of more sensical quantitative research and improve sensitivity and contextual relevance. This approach could deepen our understanding of what research results can mean for people and communities.

Challenges in adapting to contemporary issues

Over the past few years, scholars have raised significant questions about the suitability of quantitative research for addressing complex, modern problems. Critics argue that the more traditional methods of quantitative studies need help to capture the complexity of these global challenges. Quantitative research, for example, isolates variables via numbers, which can obscure the complex web of social/economic/environmental interrelation. Consequently, these types of studies could deliver a reductive perspective on topics such as climate change, which requires an integrated understanding of both terrestrial and ecological systems with human behaviour. There are many ways this limitation manifests itself; one such way is through public health studies, as a close-knit focus on specific indicators of health can shift attention away from social determinants that may play the most significant role in an outcome (e.g., access to healthcare, the culture surrounding illness and illness behaviour, community resilience).

Scholars such as Creswell (2014) and Morse (2016), who specialize in qualitative methodology, recommend combining qualitative and quantitative approaches to gain a deeper depth and richness of data collection within these contexts. Integrating both methodologies allows researchers to obtain the complexities of models or phenomena associated with contemporary issues, thus providing a much better holistic understanding of the variables under investigation. Qualitative methods, including interviews or participatory action research, can add specific colour to the stories of those facing environmental or social challenges with meaning beyond numbers. Some criticize quantitative research as making it particularly difficult to address 21st-century global problems that transcend national borders and would benefit from sen-

sitive, flexible, adaptable approaches. In response, researchers need to adopt a broader integrative approach. This approach values the variety of perspectives and methods at all levels, encouraging collaboration and interdisciplinary research. It also involves moving towards a more granular understanding of the complexity of human experience and social change, recognizing that these issues are not easily quantifiable and require a nuanced, context-specific approach.

Discussion

Defensive nature of quantitative research

A defensive stance has become entrenched in dealing with critiques, particularly those targeting the often reductionist and decontextualized quantitative research methodologies. Advocates of quantitative approaches frequently stress their accuracy and interpretation in the form of statistical analysis, which is deemed crucial for locating correlations and determining causality. Such findings are frequently heralded as evidence-informed policy and practice support, purporting to offer insight and direction towards effective solution strategies across domains, from public health to education to social policy (Park et al., 2020; Şahin & Ozturk, 2019; Zyphur & Pierides, 2020a). However, this defensive position is regularly countered by academics asserting a weaker claim on quantitative research: data can only be generalized so that potential outliers and anomalies have been accounted for in the contexts where the data was scrubbed. According to Schreier (2018), these generalizations can result in inaccurate conclusions since they need to highlight the nuance and variability of reality. This persistent conflict demonstrates an essential challenge faced by those working in quantitative research: how to render their method as both relevant and scientific amid increasing desires for nuanced yet adaptable representations of the social world.

Quantitative research is often defensively portrayed to claim the absolute realities of the objective world. It is less answered what to be done to assess the multi-realism in the advent of diverse and contrasting claims and counterclaims in theorizing the reality of the single phenomena. In the current landscape, where there is a heightened interest in socio-cultural context, qualitative detail, and participants' voices among social scientists, the quantitative researcher might find herself in a methodological dance-off. This defensive posture can take the form of refusal to engage with criticism and even consider combining alternative methods to enrich their findings. However, it is crucial to recognize that accurate understanding cannot be achieved without something more than the shallow end of analysis always undertaken by quantitative scholars. They need to learn to swim in deeper waters by learning from qualitative researchers caught up in ossified methodological camps. Embracing such dialogue and integrating qualitative methods could lead to a more comprehensive and nuanced understanding of the social world, increasing the external validity and verifiability of quantitative results.

Addressing ethical and contextual limitations

A main criticism of quantitative research is that it neglects ethical issues and the contextual elements of a partici-

pant's life. Many quantitative studies, its critics say, consist of little more than perfunctory interactions with a handful of participants — almost as though those individuals have been reduced to numbers on pages instead of stories and organisms within rich contexts. Such distance leads to ethical failures because the details of participants' lives are sacrificed or compromised for the numbers or quantified facts (Bauer et al., 2021). However, the future looks promising as methodological adaptation is going forward. Participatory approaches in quantitative designs could better understand participants' realities, paving the way toward more meaningful ethical engagement. This shift towards more participatory approaches should inspire optimism, as it promises to bring a more humanistic and ethical dimension to research.

Overcoming ethical issues in conducting quantitative studies benefits not only the research subjects via their engagement but also increases the strength of the entire process. This social responsibility or ethical practice by researchers who not only take care of personal interest but are also interested in hearing the views of their research participants. This behaviour reflects the vital role placed on both ethics and participant experience. It allows for more profound and contextualized results, as the researcher can assess the key contributing factors that may affect participants' shaping behaviours and attitudes. Moreover, engaging participants as full partners in the research process can enable communities to express their concerns and experiences that shape the research findings. In the end, the incorporation of ethical engagement into quantitative research allows for better validity in results while also promoting a culture of ethics within research. This empowerment of researchers to promote ethical engagement is crucial in this day and age where participants are often grouped as mere subjects to study rather than viewers who can trace back through a road of constructivism.

Quantitative research in the context of global issues

In an era of complexity regarding global issues, critiques of quantitative research are particularly salient as these social phenomena cannot be understood in isolation. Bryman (2012), Creswell (2014) and Timans et al. (2019), among others, have argued for methodological pluralism as a response to such complex problems that may require both quantitative and qualitative strategies. Quantitative research may provide valuable information about how widespread a problem is, but only qualitative work can reveal the social determinants and contextual factors of the problem. If both methodologies are integrated, it enables researchers with a more comprehensive view of global challenges, which rarely can be reduced to purely number data, such as climate change, poverty and health disparities.

In addition, qualitative insights combined with quantitative results increase the generalization of research findings. Qualitative research produces context-specific insights that can reveal differences between population segments, making them appropriate for adaptation to different contexts. Such adaptability is essential for social injustices and environmental sustainability, as one-size-fits-all solutions rarely work (Hammersley, 2017). Indeed, acknowledging the limitations of quantitative research enables scholars to contribute to more relevant and improved interventions by directly addressing issues related to inclusivity, complexity and context within a

domain in which these concepts seem particularly pertinent. Thus, quantitative research can change from a defensive posture to an integrated and more holistic relation that helps recognize its weaknesses and use this form's strengths, resulting in excellent yields by addressing contemporary challenges.

Conclusion

The insights that quantitative methods provide regarding disentangling complex interrelationships among various variables, thanks to their more structured and replicable methodologies, cannot be denied. However, the critiques examined in this review point to some significant limitations of this approach. Reductionism, ethical concerns, and issues with generalizability are all significant obstacles to achieving an adequate understanding of many aspects of the social world. These criticisms underscore the urgent need to rethink quantitative practices, primarily calling for a more interpretive lens that values the context and diversity of human experience. Overcoming these limitations will enable researchers to have greater transferability of their findings and be able to relate them more closely towards real-world problems.

Furthermore, in the face of the multi-faceted nature of global problems today, there is a growing need for adaptable and context-specific research approaches. The integration of qualitative insights into quantitative frameworks presents a promising solution to bridge this gap. By combining rich content knowledge with numerical outputs, this approach can bring new dimensions to understanding complex problems. The adoption of methodological pluralism, which leverages the strengths of both quantitative and qualitative methods to complement each other, promises to yield richer insights and more effective solutions to our most pressing problems. Plural perspective and strategy in methodology can better enhance triangulation, particularly in terms of paradigms, and methods. The multi-method approach, by its very nature, is designed to enhance the credibility of research results and empower researchers to respond more sensitively, inclusively, and effectively to the contemporary challenges of social science research.

Conflicts of Interest

No conflicts of interest exist.

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Імплікації та критика кількісних досліджень: Систематичний огляд

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Мета дослідження. Мета дослідження полягала у критичному аналізі складних концепцій та характеристик, пов'язаних з кількісними дослідженнями, з точки зору соціальних наук.

Матеріали та методи. На основі систематичного огляду в цьому дослідженні проведено оцінку ключових прогалин і суперечностей, виявлених у наукових працях, що були опубліковані в журналах з високим індексом цитування, а також у більш цитованих реферативних текстах. Головне аналітичне питання включало концептуалізацію кількісних методів і висвітлення різних вимірів онтології, валідності, надійності, узагальненості та етичних імплікацій.

Результати. Кількісний метод широко використовується в більшості наукових галузей, перетворюючи результати досліджень на стратегічний аналіз через статистичні та експериментальні рамки. Попри таку широку сферу застосування, результати цього дослідження вказують на наявність у кількісного методу певних обмежень і дилем, які можуть обмежити наше сприйняття і розуміння людської поведінки та соціальних явищ у суб'єктивному світі. Сприяючи розширенню бази емпіричних знань, кількісні дослідження піддаються критиці за неадекватний підхід до вивчення складних соціальних явищ, залежність від жорстких припущень і вразливість до контекстуальних чинників. Рефлексія над зазначеними обмеженнями сучасних кількісних методів впливає на визначення напрямів щодо оцінки удосконалення існуючих підходів та інтеграції альтернативних стратегій.

Висновки. Проведене дослідження дозволяє зробити висновок, що імплікації кількісного методу є раціональними, однак не мають універсального характеру. Детерміністський підхід кількісної методології може призвести до вихолощення розуміння суб'єктивного світу внаслідок свого тяжіння до абсолютних реалій. Отже, дослідження підкреслює необхідність методологічного плюралізму, заохочуючи науковців, дослідників та студентів соціальних наук та суміжних галузей бути відкритими та сприйнятливими до альтернативних дослідницьких підходів та мультиметодичних стратегій задля більш комплексного розуміння людської поведінки та суспільних явищ.

Ключові слова: дослідження, кількісна методологія, позитивізм, критика та імплікації.

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