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Influence of Intensive Interval Training Programs on the Development of Endurance in 10-Year-Old Boys

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Abstract

Objectives. This study aimed to experimentally identify and evaluate the effectiveness of using intensive interval programs to develop endurance in the educational process of 10-year-old boys.

Materials and methods. The research involved twenty 10-year-old boys. Control (n = 10) and experimental (n = 10) groups were created. Children and their parents were informed of 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). The following research methods were used: scientific and methodological literature analysis, pedagogical testing, and mathematical statistics to process research results.

Results. According to the results of the complex control of boys' endurance abilities, statistically significant changes in all indicators in both experimental ($p < 0.001$) and control groups ($p < 0.05$) were established. The positive dynamics of the results favoured the experimental group.

The most statistically significant changes took place in the experimental group on indicators of tests "Push-ups in a lying position" by 35.2% ($p < 0.001$), "Jumping with a rope for 1 min" (20.8%; $p < 0.001$), "Squatting on two legs for 1 min" (18.8%; $p < 0.001$), "From a lying position rising in a saddle for 1 min" (17.4%; $p < 0.01$). The obtained results of the final testing in tests "Hanging on bent arms' ", "Burpee test in 1 min" and "300 m run" were somewhat lower and still demonstrated statistically significant changes (13.0%, 11.4%, 6.5%, respectively, at the level of significance $p < 0.001$). General endurance developed more slowly than other types of endurance. In "Hanging on bent arms' " the change in data after the experiment in the control group was statistically insignificant ($p = 0.05$).

Conclusions. The intensive interval training method, which used specially selected exercises according to the "Tabata Protocol," promoted endurance development in 10-year-old boys.

Keywords: endurance, intensive interval training, Kyokushinkai karate, boys.

Introduction

In recent years, scientists (Akter & Bristy, 2022; Polevoy, 2023; Deng & Wang, 2024) have recorded a trend of increasing childhood and adolescent obesity. Overweight has become a global public health problem. The younger generation leads a sedentary lifestyle. Physical inactivity is considered a social disease. Younger students spend long periods of time sitting during school lessons (4 hours or more) and then spend the same amount of time doing homework, playing computer games, watching TV, etc. As a result of this lifestyle, cardiorespiratory performance, which is one of the most important indicators of physical health and is crucial for maintaining overall health and quality of life, has significantly reduced (Le & Dinh, 2022; Marchenko, Ivashchenko & Khudolii, 2023).

To address this dangerous situation among children, the WHO (WHO, 2020) recommends that children and adolescents engage in moderate to vigorous physical activity for at least 60 minutes a day throughout the week, mostly aerobic. At the same time, the time spent by the child in a sitting or lying position should be limited, especially in front of a screen for entertainment purposes.

The development of endurance abilities in this age group within the framework of strictly regulated exercise methods can lead to decreased performance, fatigue, and distraction. It is difficult for primary school children to perform tradi-

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tional aerobic physical exercises such as marathon running, swimming, cycling, and others for a long time (Unierzyski & Bogusławski, 2016; Marchenko & Handymov, 2021; Marchenko, Ivashchenko, Khudolii, & Lubchenkov, 2023).

There is a need to introduce new, more creative approaches and modern tools. Many authors recommend the use of high- and medium-intensity exercises (Martin-Smith, Cox, Buchan, 2020; Bauer, Sperlich, Holmberg, & Engel, 2022; Deng & Wang, 2024). They can be used in limited space and time during online learning.

Duncombe, Barker, Bond et al. (2022), Bauer, Sperlich, Holmberg et al. (2022), Wu, Yang, Yu et al. (2023), based on their own research, recommend integrating high-intensity interval training (HIIT) into physical education classes and adding aerobic and strength training to extracurricular activities. Litvin & Marchenko (2021), Marchenko, Khudolii, Ivashchenko & Musliumova (2023), Marchenko, Ivashchenko, Jagiełło et al. (2023) have demonstrated that a high level of motor skill development affects the successful performance of motor actions. Scientists consider endurance to be a component of the learning process, and a sufficient level of endurance development can simplify motor skill formation.

Izumi Tabata used a system of high-intensity interval training (HIIT) to develop endurance. The exercises were performed until the subjects became fatigued during the 7th or 8th set of 20-s cycling cycles with a 10-s rest between sets (Tabata, 2019). Weston, Wisløff & Coombes (2014) defined HIIT as performed at an intensity >80% (often 85-95%) of the maximum heart rate.

The constant change of different exercises with short rest intervals for recovery stimulates children's motivation and interest in physical exercises aimed at developing endurance. Therefore, the chosen topic is relevant.

The purpose of this research was to experimentally identify and evaluate the effectiveness of using intensive interval programs for the development of endurance in the educational process of 10-year-old boys.

Materials and Methods

Participants of the Study

The study involved twenty 10-year-old boys. The control (n = 10) and experimental (n=10) groups were formed. Both children and their parents were informed about the study's features 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 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 Study

The following research methods were used to address the tasks: analysis of scientific and methodological literature, pedagogical testing, and the method of mathematical statistics for processing research results.

The testing program included generally accepted tests: push-ups in a lying position, sit-ups in 1 min from the supine position, bent arm hang, 300 m run, "Burpee" test in 1 min, jump rope in 1 min, and double leg squats in 1 min.

The study was conducted from September to May 2023-2024 at the sports club "Centaur" in Kharkiv. The study involved twenty 10-year-old karate athletes in their third year of training. Control (CG) and experimental (EG) groups were formed, with 10 participants in each group. The ratio of training sessions in both groups followed the recommendations of the standard Kyokushinkai karate program for children's and youth sports schools (Goncharenko, 2021). The formative experiment lasted 12 weeks.

In the classes of the EG, a set of exercises based on the "Tabata Protocol" was additionally used. Exercises were performed for 20 seconds, followed by a 10-second rest. This cycle was repeated 8 times consecutively, making the total time of one block 4 minutes (Tabata, 2019). The boys performed 3 blocks, totaling 12 minutes. Exercise complexes targeting different endurance components were performed at the end of each session. Both groups trained 3 times a week for 2 academic hours per session.

To determine training loads, we used the Tanaka formula to calculate the maximum heart rate.

$$HRmax = 208 - 0.7 * age$$

The boys performed exercises at an intensity reaching 80-85% of their maximum heart rate. The physical exercises forming the basis of intensive interval training were performed according to the Tabata Protocol:

1. Run on the Spot: Perform at maximum speed.
2. Mae Hiza Geri: From the "Yoi dachi" stance with hands on the belt, perform knee strikes forward above the belt, alternating legs.
3. Kangaroo Exercise: Perform jumps on the spot, pulling knees to the chest during the jump.
4. Mountain Climber: From a lying position, pull knees to the chest, alternating legs.
5. Leg Change in Zenkutsu-dachi Stance: Start in a left-handed stance. When changing the position of the legs, comply with the requirements of the stance technique (Marchenko & Taranenko, 2020). Hands on the belt.
6. Heisoku Dachi to Kiba Dachi Transition: From a stance with legs together ("Heisoku dachi"), arms down, hands open, and palms pressed to the hips, transition with a jump to a wide stance with legs apart ("Kiba dachi"), arms through the sides up, performing a clap with palms above the head. Pay attention to the correctness of the Kiba dachi stance: the distance between the feet should be two shoulder widths. The feet are parallel and fully supported on the floor. The back is straight and perpendicular to the floor. The hips are slightly angled to the floor, parallel in a low stance. Keep knees to the sides. The body weight is evenly distributed on both legs (Litvin & Marchenko, 2021; Marchenko, Khudolii, Ivashchenko & Musliumova, 2023).
7. Mae Geri Kicks: From a kneeling position, alternate kicks with the right and left legs. Begin in a stance on the right knee. The thigh of the right leg is perpendicular to the floor, the left leg is bent and positioned forward, standing on the whole foot so that its shin is parallel to the thigh of the right leg. Maintain an upright torso during the exercise (Marchenko & Kovalenko, 2020; Marchenko, Ivashchenko, Jagiełło et al., 2023).

8. Burpees: Perform in the following sequence: squat, lie down, push up once, squat, jump up, and clap palms above the head during the jump (Serhiienko, 2010).

Statistical Analysis

Data were collected and organized using the EXCEL program and analyzed using the IBM SPSS 26 statistical package. The following parameters were calculated: arithmetic mean (mean), standard deviation (SD), and standard error of the mean (SEM). Comparison of the arithmetic means was performed using Student's t-test for dependent samples and Student's t-test for independent samples. The hypothesis of normality of data distribution was determined using the Shapiro-Wilk test. The hypothesis of equality of variances among the compared groups was determined using Levene's test.

Results

The algorithm for processing the results was as follows: first, the study materials were processed in a consolidated group of children (n=20). The statistical analysis of endurance indicators among 10-year-old boys was carried out (Table 1). Indicators of the ability to display different types of endurance generally correspond to age norms. The sample was tested for normality of indicator distribution. Given that our sample was small (n=20), we used the nonparametric Shapiro-Wilk test to determine the normality of the data distribution (Table 2). The obtained values indicated that the significance level was $p > 0.05$ for all tests. Then, using the random numbers method, the sample was divided into an experimental group (EG) (n = 10) and a control group (CG) (n = 10) of students who participated in the developed research program.

The obtained p-level of Levene's test > 0.05 (p-value ranging from 0.271 to 0.744) indicates that the variances of the compared distributions of values do not differ statistically significantly (Table 3). Therefore, it was decided to use the first type of Student's t-test (assuming equality of variances). The t-test results indicate that the difference between the samples of the experimental and control groups was not statistically significant (p-level > 0.05).

The data obtained during the formative experiment are presented in Table 4. The efficiency of using intensive interval exercises for developing endurance in 10-year-old boys was studied. According to the results of the comprehensive assessment of the boys' endurance abilities, statistically significant changes in all indicators were observed in both the experimental and control groups ($p < 0.05$). The positive dynamics of the results favored the experimental group.

The most statistically significant changes in the experimental group were observed in the following tests: "Flexion and extension of hands in a lying down support" (an increase of 35.2%; $p < 0.001$), "Jumping with a rope for 1 min" (20.8%; $p < 0.001$), "Squatting on two legs for 1 min" (18.8%; $p < 0.001$), and "From a position lying on the back, rising to a seated position for 1 min" (17.4%; $p < 0.01$).

The results of the final test in the "Bent arm hang," "Burpee test in 1 min," and "300 m run" showed somewhat lower but still statistically significant changes (13.0%, 11.4%, and 6.5%, respectively, at the significance level $p < 0.001$). General endurance developed more slowly compared to other types of endurance. In the "Bent arm hang," the change in data after the experiment in the control group was statistically insignificant ($p = 0.05$).

Discussion

The study hypothesized that the use of specially selected exercises based on the Tabata Protocol and the intensive interval training method would contribute to endurance development in 10-year-old boys. Previous studies by Ratel,

Table 1. Statistical description of endurance indicators among 10-year-old boys

Tests	Min	Max	Mean	SEM	SD	Skewness	SDS	Kurtosis	SEK
Push-ups in a lying position, times	8.0	21.0	13.90	0.864	3.865	0.261	0.512	-0.618	0.992
Sit-ups in 1 min from the supine position, times	20	32.0	26.05	0.890	3.980	-0.058	0.512	-1.346	0.992
Bent arm hang, s	8.0	26.0	16.00	1.254	5.610	0.463	0.512	-0.983	0.992
300 m run, s	63.0	85.0	74.80	1.428	6.387	-0.063	0.512	-0.855	0.992
"Burpee" test in 1 min (cycles)	11.0	24.0	17.80	0.936	4.188	-0.164	0.512	-1.204	0.992
Jump rope in 1 min, times	37.0	70.0	54.70	2.240	10.016	0.014	0.512	-1.006	0.992
Double leg squats in 1 min, times	28.0	43.0	36.90	0.794	3.553	-0.566	0.512	0.849	0.992

Table 2: Normality of data distribution according to the Shapiro-Wilk test

Tests	the Shapiro-Wilk test		
	Statistics	df	Mean
Push-ups in a lying position, times	0.959	20	0.516
Sit-ups in 1 min from the supine position, times	0.928	20	0.142
Bent arm hang, s	0.935	20	0.191
300 m run, s	0.972	20	0.792
"Burpee" test in 1 min (cycles)	0.941	20	0.247
Jump rope in 1 min, times	0.964	20	0.624
Double leg squats in 1 min, times	0.972	20	0.801

Table 3. Characteristics of endurance indices of the studied groups at the beginning of the experiment

Indicators studied	Levene's criterion for equality of variance	t-test for equality of means						
	F	Mean	t	Sig. (double-sided)	MD	MSED	95% confidence interval for the difference	
							Lower	Upper
Push-ups in a lying position, times	0.339	0.567	0.685	0.502	1.2	1.753	-2.483	4.883
Sit-ups in 1 min from the supine position, times	0.252	0.622	0.384	0.705	0.7	1.821	-3.126	4.526
Bent arm hang, s	0.305	0.587	0.708	0.488	1.8	2.543	-3.542	7.142
300 m run, s	0.864	0.365	-0.62	0.543	-1.8	2.904	-7.901	4.301
"Burpee" test in 1 min (cycles)	0.532	0.475	0.739	0.47	1.4	1.896	-2.583	5.383
Jump rope in 1 min, times	0.11	0.744	-0.174	0.864	-0.8	4.598	-10.461	8.861
Double leg squats in 1 min, times	1.289	0.271	0.369	0.716	0.6	1.626	-2.816	4.016
Assume equal variance levels								

Table 4. Characteristics of the influence of intensive interval exercises on endurance development in 10 year-old-boys

Indicators studied	Groups	Paired differences					t	Sig. (double-sided)	%
		Mean	SD	SME	95% confidence interval for the difference				
					Lower	Upper			
Push-ups in a lying position, times	EG	-5.10	1.595	0.504	-6.241	-3.959	-10.11	0.000	35.2
	CG	-1.70	1.337	0.423	-2.657	-0.743	-4.019	0.003	12.8
Sit-ups in 1 min from the supine position, times	EG	-4.60	2.836	0.897	-6.629	-2.571	-5.129	0.001	17.4
	CG	-2.50	0.707	0.224	-3.006	-1.994	-11.18	0.000	9.7
Bent arm hang, s	EG	-2.20	0.632	0.200	-2.652	-1.748	-11.00	0.000	13.0
	CG	-0.70	0.978	0.309	-1.399	-0.001	-2.264	0.050	4.6
300 m run, s	EG	4.80	2.044	0.646	3.338	6.262	7.426	0.000	6.5
	CG	1.50	1.650	0.522	0.320	2.680	2.875	0.018	2.0
"Burpee" test in 1 min (cycles)	EG	-2.10	0.876	0.277	-2.726	-1.474	-7.584	0.000	11.4
	CG	-1.00	0.667	0.211	-1.477	-0.523	-4.743	0.001	5.8
Jump rope in 1 min, times	EG	-11.30	6.255	1.978	-15.774	-6.826	-5.713	0.000	20.8
	CG	-3.30	2.214	0.700	-4.884	-1.716	-4.714	0.001	6.0
Double leg squats in 1 min, times	EG	-7.00	3.018	0.955	-9.159	-4.841	-7.334	0.000	18.8
	CG	-2.90	0.994	0.314	-3.611	-2.189	-9.222	0.000	7.9

Lazaar, Dore, et al. (2004), Costigan, Eather, Plotnikoff, et al. (2015), and Eddolls, McNarry, Stratton, et al. (2017) demonstrated the success of including intensive interval training in school schedules. We suggested incorporating these exercises into the educational and training programs for karate athletes at the initial stages, supplemented with simple karate elements. The final testing revealed that these complexes significantly influenced the level of endurance development in the experimental group (EG). The dynamics of the results for all exercises were statistically significant ($p < 0.001$).

Our results align with the findings of Ratel, Lazaar, Dore, et al. (2004), Vasconcelos, Protzen, Galliano, et al. (2020), which showed that children recover faster from high-intensity exercise than adults. Exercises repeated at high speed and separated by short rest periods can improve aerobic and anaerobic performance. According to Duncombe, Barker, Bond, et al. (2022), Bauer, Sperlich, Holmberg, et al. (2022), and Wu, Yang, Yu, et al. (2023), high-intensity interval training (HIIT) improves muscular and aerobic fitness.

Our findings confirm those of Cao, Quan, and Zhuang (2019), Tottori, Morita, Ueta, et al. (2019), and Vasconcelos, Protzen, Galliano, et al. (2020) regarding high-intensity interval training as a promising, time-efficient method for endurance development. However, it should be noted that the physical fitness and health of modern Ukrainian pupils studying online call into question the use of high-intensity exercises. This condition requires a gradual increase in intensity with constant monitoring of external signs of fatigue and the cardiovascular system (HR) response to adjust the proposed load (Nurkholis, et al., 2023).

As practice and the results of previous studies (Masanovic, Gardasevic, Marques, et al., 2020; Marchenko, Ivashchenko, Khudolii, & Lubchenkov, 2023) have shown, primary school pupils find it very difficult to sustain physical activity for extended periods. They are not psychologically or physically prepared to overcome difficulties. The authors emphasize the importance of using both game- and competitive exercise methods in physical education and sports training,

especially when developing endurance. We used the competitive method and musical accompaniment to stimulate effort and increase interest during the experiment.

In terms of general endurance in the 300-m run test, boys showed a significant lag, which is consistent with the findings of Marchenko, Ivashchenko, Khudolii, & Lubchenkov (2023). Interval training improved muscular endurance during squats, consistent with the findings of Tottori, Morita, Ueta, et al. (2019).

Since the intensity of the work performed by the karate boys reached 80%-85% of their maximum heart rate, we agree with Tabata's opinion that training that uses other types of exercises, including running, jumping, burpee, and others, although performed similarly to the Tabata Protocol, are not high-intensity exercises. A real Tabata workout consists of 7-8 exhausting sets of high-intensity exercises. In his opinion, only motivated athletes can participate in such training (Tabata, 2019).

We agree with Gäbler, Prieske, and Hortobágyi (2018), as well as Hontarenko, Marchenko, and Korol (2022), that integrating endurance training with other motor skills (e.g., strength, coordination) has a more effective impact on physical fitness and sports performance in pupils than unidirectional training.

Conclusions

An analysis of global and Ukrainian scientific research, along with personal experience, indicates that martial arts are intermittent by nature, consisting of periods of high-intensity and low-intensity efforts with pauses during competition rounds. Most authors believe that intensive interval training is one of the best methods for improving cardiorespiratory fitness in healthy children and adolescents. Given its efficiency and effectiveness, it can be an effective approach for improving physical activity, health, and fitness, strengthening interest in exercise, and achieving high competition results.

Assessing the level of endurance in 10-year-old boys after classes incorporating intensive interval training supplemented with elements of karate demonstrated significant statistical changes in endurance indicators. Notably, there were improvements in exercises characterizing the development of local dynamic power endurance of different muscle groups (strength of arms, legs, and core muscles) and coordination endurance ($p < 0.001$).

Determining the effects of training according to the "Tabata Protocol" using exercises that imitate Kyokushinkai karate classes is valuable considering the specifics of training and its effects on sports performance. Further research can evaluate the impact of intensive interval training on Kyokushinkai karate competition results. Future research protocols should consider the number of strikes and technical skills used in combat.

Conflict of Interest

The authors declare no conflicts of interest.

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Вплив інтенсивних інтервальних програм на розвиток витривалості хлопців 10 років

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 4 табл., 35 джерел.

Метою даного дослідження було експериментальне виявлення та оцінка ефективності використання інтенсивних інтервальних програм розвитку витривалості у навчальному процесі хлопчиків 10 років.

Матеріали і методи. У дослідженні взяли участь 20 хлопців 10 років. Були створені контрольна (n = 10) та експериментальна (n = 10) групи. 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). Дослідження проведено відповідно до Гельсінської декларації – етичні принципи медичних досліджень за участю людей (World Medical Association Declaration of Helsinki, 2013). Були застосовані такі методи дослідження: аналіз науково-методичної літератури, педагогічне тестування та методи математичної статистики обробки результатів дослідження.

Результати. За результатами комплексного контролю здібностей хлопців до витривалості встановлені статистично достовірні зміни за всіма показниками як в експериментальній ($p < 0,001$), так і контрольній групах ($p<0,05$). Позитивна динаміка результатів відбулася на користь експериментальної групи.

Більше за все статистично значимі зміни відбулися в експериментальній групі за показниками тестів «Згинання і розгинання рук в упорі лежачи» на 35,2% ($p < 0,001$), «Стрибки зі скакалкою за 1хв» (20,8%; $p < 0,001$), «Присідання на двох ногах за 1 хв» (18,8%; $p < 0,001$), «З положення лежачи на спині піднімання в сід за 1хв» (17,4%; $p < 0,01$). Отримані результати підсумкового тестування у тестах «Вис на зігнутих руках», «Тест Берпі за 1 хв», «Біг 300 метрів» були дещо нижчі та все ж продемонстрували статистично значимі зрушення (13,0%, 11,4%, 6,5% відповідно, при рівні значимості $p<0,001$). Загальна витривалість розвивалась повільніше по відношенню до інших видів даної здібності. У «Висі на зігнутих руках» зміна даних після експерименту в контрольній групі виявилась статистично не значимою ($p = 0,05$).

Висновки. Використання спеціально підібраних вправ за «Протоколом Табата» методом інтенсивного інтервального тренування сприяло розвитку витривалості у хлопців 10 років.

Ключові слова: витривалість, інтенсивне інтервальне тренування, кіокушинкай карате, хлопці.

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